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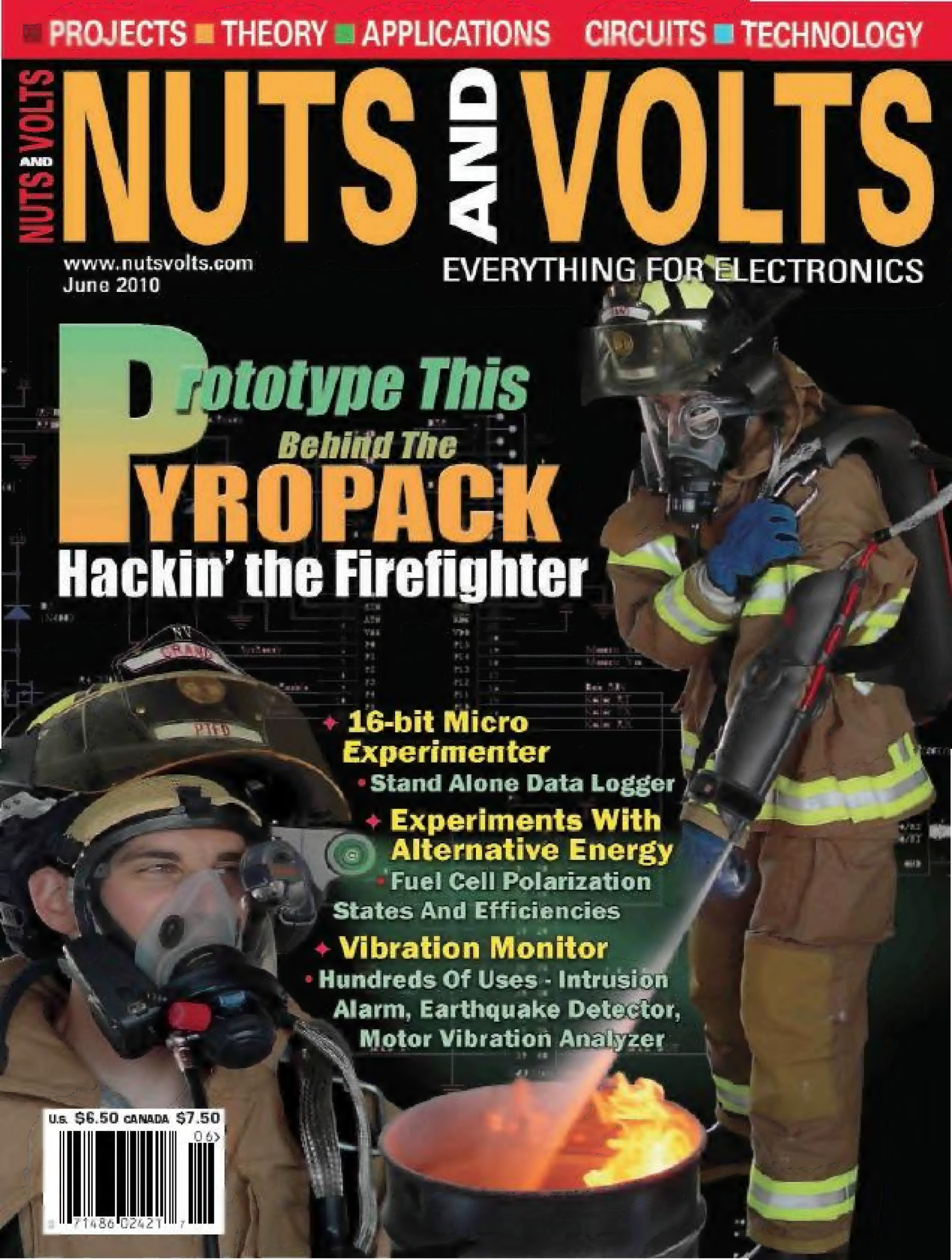

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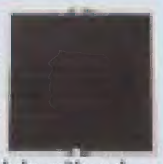

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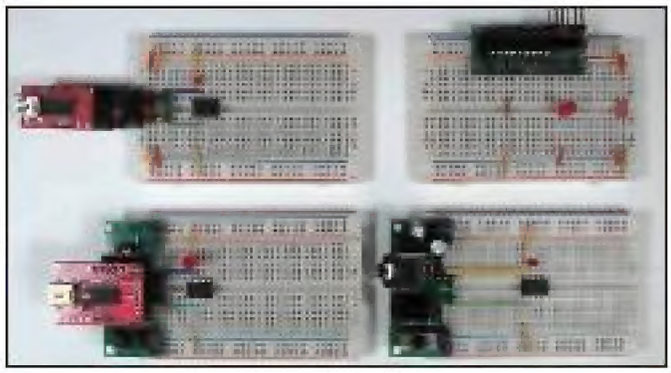
Page 14

Page 33



Page 52

Projects & Features

28 Implementing a Data Logger with the 16-bit Micro Experimenter
As we build on our Experimenter board, this time we'll add a stand-alone data logging application.
By Thomas Kibalo

33 Shake, Rattle, and Roll Vibration Monitor
There's a whole lotta shaking goin' on, and now you can keep track of it.
By Ron Newton

40 The Projects of Prototype This!
Joe Grand takes a closer look at the electronic aspects of his different builds from the popular Discovery Channel show Prototype This! This month, get behind the PyroPack.
With Joe Grand

46 Experiments with Alternative Energy
Learn the fundamentals of renewable energy through this educational series.
This month: Fuel Cell Polarization States and Efficiencies.
By John Gavlik

FUNdamentals For Beginners

Just getting started in electronics? Try these simple demos to illustrate electronics principles and how components function in actual circuits!

38 Resistors
65 How a Speaker Works

Columns

10 TechKnowledgey 2010
Events, Advances, and News
Return of the memristor, home for Mac orphans, new Class-D audio amps, plus some other stuff you'll find interesting.

14 Open Communication
The Latest in Networking and Wireless Technologies
Experimenting with Commercial Wireless Modules.

20 Q & A
Reader Questions Answered Here
Low voltage warning, alternator regulator, magnetic questions, Geiger counter, plus more.

52 PICAXE Primer
Sharpening Your Tools of Creativity
Using the AxMate Power and Programming Adapter.

58 The Design Cycle
Advanced Techniques for Design Engineers
ZeroG Goes USB.

67 Smiley's Workshop
Programming • Hardware • Projects
AVR Memory — Part 1: Introduction.

Departments

08 DEVELOPING PERSPECTIVES
26 NEW PRODUCTS
36 SHOWCASE
66 ELECTRO-NET
72 NV WEBSTORE
76 CLASSIFIEDS
78 TECH FORUM
81 AD INDEX

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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

The Microcontroller Debate

If you're an experienced microcontroller experimenter, you probably have a favorite chip or configuration — maybe a Microchip PIC, a Parallax BASIC Stamp or Propeller, or an ATMEL-based Arduino — and good reasons for your choice. Moreover, if you've worked with a particular microcontroller on several projects, you've no doubt developed a bag of tricks and workarounds that enable you to do just about anything you want. I'm sure you can defend your choice based on relative cost, performance, or ease of use.

However, if you're just starting out in your exploration of microcontrollers, you have some decisions to make. Picking a microcontroller line is a big step, and one that deserves a bit of thought. The initial cost of the chip or board is typically trivial compared with the cost of accessories, books, and — most importantly — your time. You'll have to invest time to learn how to properly configure the hardware, time to become fluent in the programming language, and time to get used to debugging the system.

Before I offer my advice, let me state that there's no single best solution. Every product on the market has strengths and limitations. If you drop into the various forums on the web, you can read the myriad opinions why one particular microcontroller is better than all the others. The solution that's best for you depends on your experience and what you expect to get out of working with a microcontroller.

In my opinion, if you're new to microcontrollers, you can't go wrong with the BASIC Stamp line of microcontrollers. A major strength of the Stamp is documentation — critically important to a novice. There are hundreds of articles and dozens of books devoted to the Stamp. Moreover, Parallax offers educational kits that include sensors and servos, and extensive documentation and source code for these peripherals. The Stamp boards are simple to set up and program. Even if you've never touched a microcontroller before, you can be up and running in less than an hour. The BASIC Stamp is still my microcontroller of chioice if the application has to be ready yesterday.

Parallax also sells a higher-performance Propeller chip. I've used the Propeller on several projects, and it's both powerful and relatively easy to program. However, I think a novice might have a rough time getting the most out of the cogs and other non-standard architecture of the Propeller. This unique chip also uses a non-standard language called SPIN. If your goal is to understand different microcontroller architectures, then the Propeller chip may be just the thing for you. However, knowledge of SPIN doesn't readily translate to other microcontrollers on the market.

When I started developing semi-autonomous robots, I was forced to look for something more powerful than the Stamp, and turned to the ATMEL line of processors. The cost for this step up in processing power, number of I/O ports, and other features was considerable. Instead of a simple USB connection between my PC and the Stamp, I had to purchase and learn to use a programmer. Then, there was the C compiler and the compile-run process instead of the instantaneous, interpreted Basic with the Stamp.

In retrospect, the progression from Stamp to bare ATMEL microcontroller was fortunate. It allowed me to learn to use a variety of sensors and servos in an interactive environment. In the less forgiving, more time-consuming compiler environment, it would have taken me much longer to learn to use the hardware. I think the same analysis holds true for the PIC — which I consider a top-notch production chip that can go toe-to-toe with the ATMEL.

I can't speak from experience on the Arduino as a first microcontroller. However, it was designed as a painless introduction to microcontrollers, and it appears to be successful on that account. I've worked with the programming environment – which, by the way, is compatible with a Mac – and it's solid and easy to use.

Moreover, there are dozens of add-on boards or shields, and multiple form factors to choose from. For example, I've used the Duemilanove — an ATMega328-based board — and it's a pleasure to work with. I'm currently working on the LilyPad: a machine-washable, sew-on version of the Arduino from SparkFun (**www.sparkfun.com**) to try out some body network ideas.

If you're deciding between the BASIC Stamp and Arduino for a beginner's system, then relax. You can't go wrong with either platform. However, if you want to learn or know how to program in C, then the Arduino is probably a better choice. On the other hand, if you're comfortable with Basic and your focus is to learn about sensors, actuators, and other peripherals, then the Stamp may be a more efficient vehicle. I also think the Parallax-backed support forums are second to none — something to consider when you need help sorting out those input/output signals. **NV**

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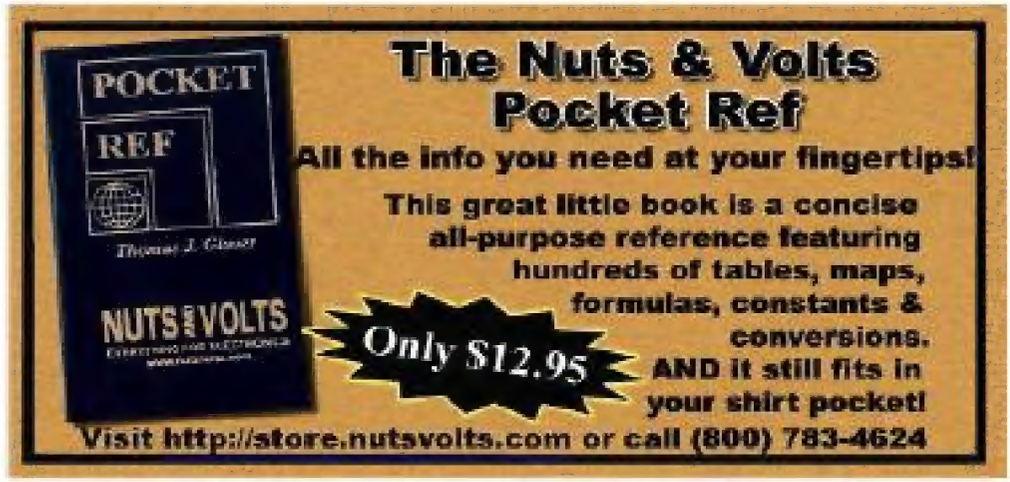
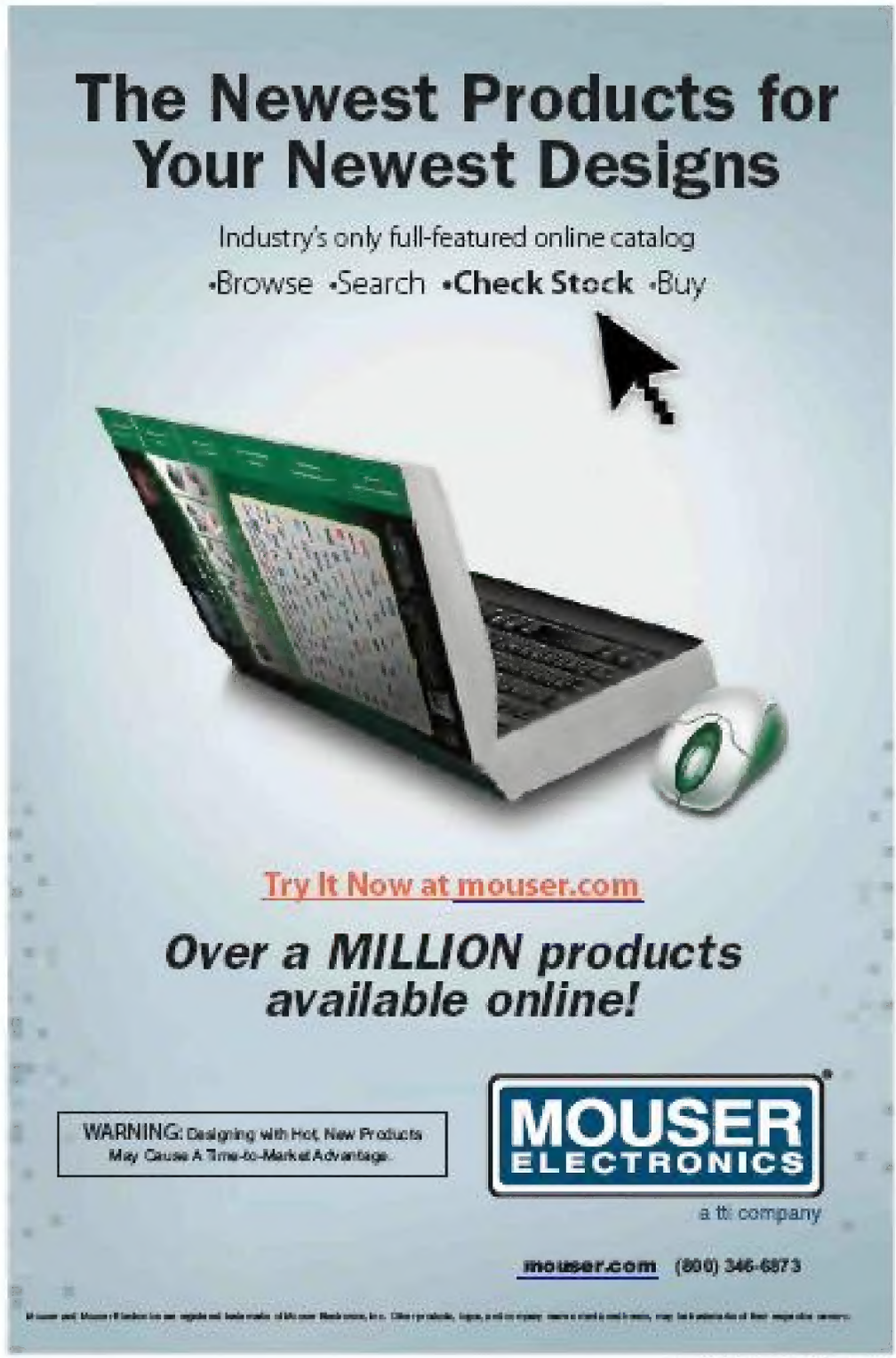




TECH KNOWLEDGEY 2010

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

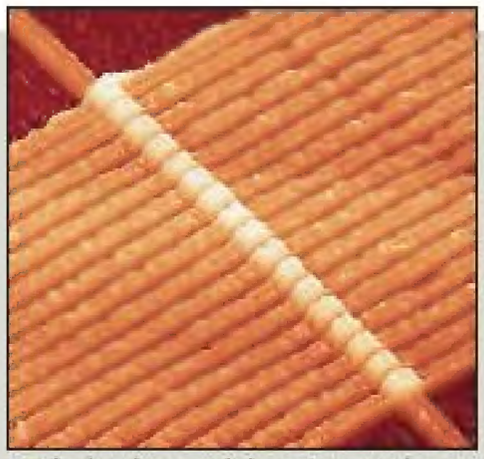
ADVANCED TECHNOLOGY

RETURN OF THE MEMRISTOR

In the July '08 issue, we reported the invention of the memristor at Hewlett-Packard Labs (www.hpl.hp.com) which they called the "fourth basic circuit element," along with resistors, capacitors, and inductors. At the time, it was thought to mainly provide a possible way to replace DRAMs with static ICs to lower power consumption and eliminate the boot-up process. However, HP recently announced that the concept has even more importance than originally believed. They have discovered that the device — in addition to use in memory storage — can perform logic functions. This implies that a memristor circuit could be used to perform computations in the device where the data is stored, thus eliminating the need for a CPU altogether.

Each memristor is composed of two layers of titanium dioxide connected by wire. As current is applied to one layer, the small signal resistance of the other layer is changed, and this may be used as a method to register data.

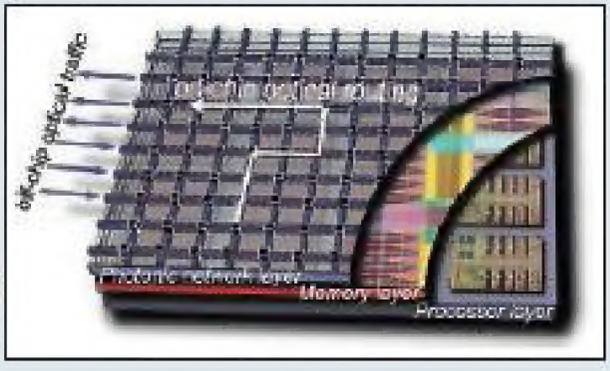
Pushing ahead with the technology, HP has created development-ready architectures for the ICs and believes that they could be on the market relatively soon. They also have figured out how to stack multiple layers of memristors in the same chip to make them highly compact. A spokesman projected, "In five years, such chips could be used to create handheld devices that offer ten times greater embedded memory than exists today, or to power supercomputers that allow work like movie rendering and genomic research to be done dramatically faster than Moore's Law suggests is possible." Memristors also use less energy and operate at higher speeds than things like Flash memory, and can store double the information in the same space. Also commenting on the development was R. Stanley Williams, HP senior fellow and founding director of the HP Quantum Science Research group: "Since our brains are made of memristors, the flood gate is now open for commercialization of computers that would compute like human brains, which is totally different from the von Neumann architecture underpinning all digital computers." ▲



■ A circuit containing 17 memristors as seen by an atomic force microscope.

SO LONG, COPPER

Meanwhile, IBM is taking an entirely different approach to preserving Moore's Law with its "nanophotonic avalanche photodetector," so-named because an incoming light pulse triggers the release of a few charge carriers, each of which frees some others, and so on, until the original signal has been amplified several times. Until recently, existing avalanche devices could not be used to detect fast optical signals because the avalanche effect took too long to build up. However, the new device — said to be the fastest ever built — can receive optical data at a rate of 40 GBps and simultaneously multiply them by ten. Plus, they operate with a supply of just 1.5V, so they could conceivably be powered by an AA battery instead of the 20V to 30V required by conventional devices. According to IBM, being based on standard silicon and germanium, it can be produced using standard chip manufacturing processes. The bottom line is that it may soon be possible to replace the copper wires between computer chips with light pulses. According to Dr. T. C. Chen, a VP at IBM Research (www.watson.ibm.com), "With optical communications embedded into the processor chips, the prospect of building power-efficient computer systems with performance at the exaflop level might not be a very distant future. "For details, pick up a copy of the March '10 issue of *Nature* (www.nature.com). ▲

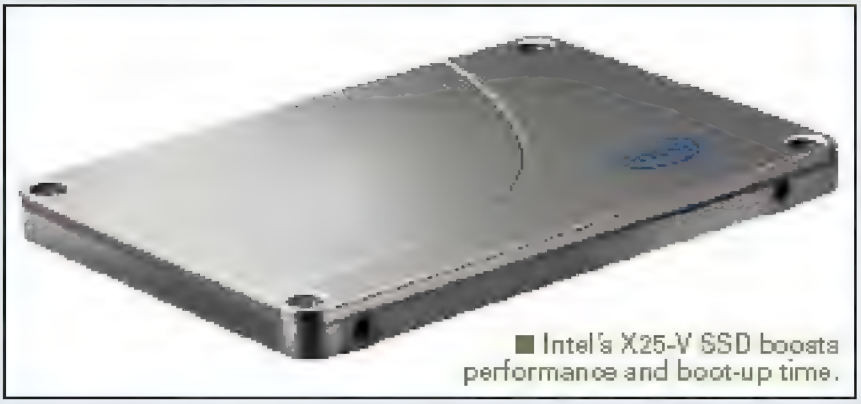


■ Bushnell's Nightwatch displays objects at up to 200 ft.

COMPUTERS AND NETWORKING

LOW-END SSD ADDED TO LINEUP

Solid-state drives (SSDs) still can't compete with platter-based storage devices on a cost-per-byte basis, but the X25-V SSD from Intel (www.intel.com) edges a little closer at about a $120 street price for this 40 GB unit. The internal SATA (1.5 or 3.0 Gb/s interface) drive is intended to enable "value segment" notebooks, as well as dual drive/boot drive desktops to include the advantages of solid-state computing at an entry-level price. A cited example of how you might make good use of the drive would be to configure it as your boot drive and load the Office suite on it, as well. Not only would your boot-up time be reduced, the Office applications would run up to 43 percent faster. The X25-V is actually "low man on the totem pole" of Intel SSDs; you can also get one with 80 or 160 GB total capacity for about $200 and $450, respectively. The unit is rated for 1.2 million hours MTBF, which is probably overkill unless you plan to use your laptop for another 137 years. It also works in temperatures up to 70°C (158°F), so even if you live in a mud hut in Death Valley, you're good to go. ▲



■ Intel's X25-V SSD boosts performance and boot-up time.

NO IE FOR XP

The news is not so bright for folks who still cling to Windows XP and want an upgraded Internet Explorer. It recently became official that IE v. 9 will not support XP. But before waxing cynical, it should be noted that there is more at work here than just Microsoft's desire to extract money from your pocket. A spokesman explained that IE9's graphics acceleration depends on Direct2D and DirectWrite DirectX application programming interfaces, and support for them "cannot be extended to Windows XP." This puts Microsoft in the odd position of releasing an IE version that will run on fewer than a third of existing Windows machines. In any event, it appears that Firefox, Chrome, and even Safari will support XP for the time being, so you can keep on clinging. ▲

HOME FOR MAC ORPHANS

When Apple (www.apple.com) dumped its traditional operating system in 2002 and went to the UNIX-based OS X, it showed some mercy toward Mac owners who had tons of money invested in software that ran only on System 9.x and earlier by packaging a "Classic" environment with it. But Classic doesn't run on Intel-based Macs, and as of OS X v. 10.5 (Leopard), it has been eliminated entirely. This leaves PowerPC Macs with the choice between never upgrading the OS or dumping all Classic software. However, there appears to be a solution for both PowerPC and Intel machines in the form of SheepSaver — a free download from sheepshaver.cebix.net. It hasn't been tested here, and it appears to be somewhat less than seamless in operation, but many positive reviews of it can be found on the Internet. The website notes that it runs "with a varying degree of functionality" on Unix with X11, Mac OS X, Windows NT, and BeOS R4/R5. One small snag is that Intel Macs can't run it without downloading an image of the Power Mac ROM, but that doesn't appear to be difficult. The good news is that applications run at native speed, i.e., there is no emulation involved. So even if SheepSaver isn't perfect, if you have been orphaned by v. 10.5, it's probably worth a try. ▲

INDUSTRY AND THE PROFESSION

PROGRAMMER GETS FOUR YEARS

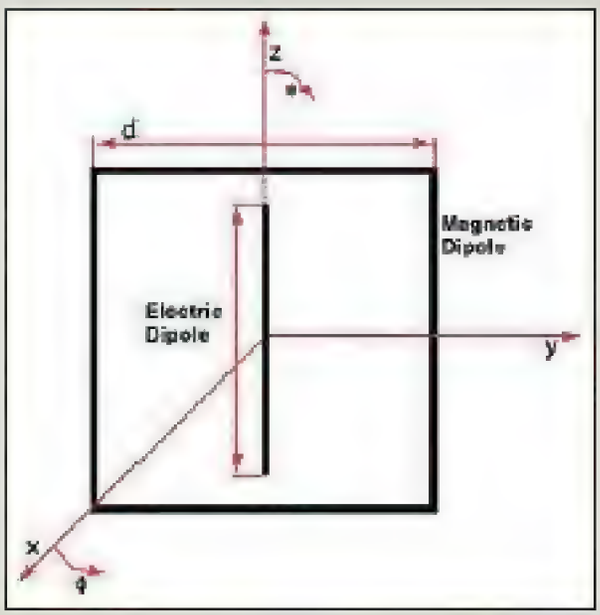
In August '08, former Barclay's Bank programmer, Humza Zaman, was arrested for numerous offenses including money laundering, illegal computer access, identity theft, and wire fraud for his part in the theft of data from TJX (parent company of T. J. Maxx, Marshalls, et al.), BJ's Wholesale Clubs, and other retail stores. In April of last year, he pleaded guilty and now has been sentenced to four years in prison and fined $75,000. Zaman assisted ringleader Albert Gonzales in the pilfering of more than 130 million credit and debit card records and an estimated $600,000 to $800,000 in cash. Gonzales is presently awaiting sentencing but could get up to 17 years. Zaman has blamed his involvement on a lifestyle of partying and recreational drug use that required cash beyond his legitimate six-figure income. Hey, times are tough. ▲

ENTER THE 3D WORLD

■ Panasonic's 3D camcorder, part of the Viera 3D product lineup.

If your goal is to become the ultimate couch potato, Panasonic is now offering a package of consumer products that may make your living room seem more real than reality itself — or at least a lot more desirable. Following up on its goal of ruling the world of three-dimensional entertainment, it now offers 3D Viera Plasma HDTV sets, a Blu-ray 3D disk player, a 3D camcorder, and (of course) the special glasses needed to absorb it all. Video options include screen sizes from 50 to 65 inches, and each TV comes with (only) one pair of Panasonic 3D eyewear. (The company also has built a 152 inch plasma display, but it isn't included in the Viera lineup at this point.) The disc player can handle 3D media but is also compatible with various audio standards, and it upconverts standard definition video formats to 1080p. It also plays standard Blu-ray discs, DVDs, and CDs. Possibly the best part is the 3D camcorder which frees you from dependence on commercial products. Now you can record your own 3D movies with all of your friends and relatives sticking anything they want right into a viewer's face. No prices were announced as of press time, but "cheap" probably won't be an accurate description. ▲

COMPOUND ANTENNA BOOSTS PERFORMANCE



■ CPL™ design concept with electric dipole along the z axis and magnetic loop in the y-z plane.

In March, startup Dockon, Inc. (www.dockon.com), announced the availability of "the first commercially available compound PxM Loop (CPL) antenna for embedded product designs," claiming that it increases radiation efficiency, intensity, directivity, and radiated power for a given input in a small package. The trick is that the CPL devices combine magnetic loop radiators with electric field radiators, whereas conventional antennas typically use only one or the other. According to Dockon, the simultaneous excitation of both radiators "results in an effective cancellation of reactive power, improving the overall performance and efficiency to approximately 90 percent." The CPL can be manufactured with conventional PCB techniques and offers a bandwidth greater than 1 GHz. According to CEO Patrick Johnston, "After years of development, testing, and refinement of the development process, the CPL delivers on the promise of compound antenna technology in an easy to manufacture format. CPL is a revolution in antenna design offering a more powerful and efficient radiator over a wider band in a smaller footprint than before possible." Licensing to OEMs will begin soon, so look for it to appear in the next generation of wireless devices including mobile computing devices, industrial controls, automotive, aerospace, medical, military applications, and consumer electronics. ▲

NEW CLASS-D AUDIO AMPS

Also designed as embedded components for smart phones, GPS units, and a range of other handheld devices are Analog Devices' SSM2375 (mono) and SSM2380 (stereo) amplifiers. Both allow designers to employ fixed or programmable gain settings, and the latter incorporates an I²C interface that allows gain stages to be set from 1 to 24 dB (plus mute) in 47 steps without the need for external components. The programmable interface also allows independent L/R channel shutdown, a low EMI emission control mode, and programmable automatic level control functions. You get a 100 dB SNR, and Analog claims 93 percent power efficiency at 5V while running 1.4W into an eight ohm speaker. The SSM2375 provides five-level gain setting in 3 dB stages from 0 to 12 dB. Operating from a 2.5V to 5.5V supply, it delivers 3W continuous output with <1 percent THD when driving a three ohm load. The little guys are priced at $0.57 and $0.75 in quantities. For details, visit www.analog.com. NV

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BY LOUIS E. FRENZEL W5LEF

EXPERIMENTING WITH COMMERCIAL WIRELESS MODULES

Wireless *everything*. That is what I am seeing more and more. Practically every electronic product these days has some kind of wireless component or function to it. That's why it makes sense to learn more about wireless. As you are experimenting with electronic products, you may discover some devices you want to imbue with wireless capability.

Adding wireless functionality is easy these days. Transmitter, receiver, and transceiver chips are cheap and plentiful. Plus, these chips are incorporated into complete modules you can buy ready to use. Just add a battery, antenna, and some inputs or outputs. Recently, I was searching for some inexpensive modules to use in a college course lab as demos of basic wireless techniques. I found several, but I ended up with some products from Linx Technologies (www.linxtechnologies.com). This company has a wide range of chips, modules, and accessories that use low power, short range wireless in the ISM (industrial-scientific-medical) bands from about 300 MHz to 2.4 GHz. I chose the 900 MHz products.

Anyway, here is the result of my initial experimentation with these modules. Hopefully, this will encourage you to do some wireless experimentation yourself.

SOME WIRELESS BASICS

Most short-range wireless uses the FCC (Federal Communications Commission) designated license-free ISM bands. Some typical frequencies are 315 MHz, 433 MHz, 902-928 MHz, and 2.4 GHz. You can buy ready to use chips or modules for any of these bands. The 315 and 433 MHz frequencies are widely used in things like garage door openers and remote temperature gauges. The 2.4 GHz band is used for everything like Wi-Fi, Bluetooth, ZigBee, cordless telephones, and even your microwave oven. I decided not to use that popular band. Instead, I went for the 902-928 MHz products. These offer good range and the antennas are short. Furthermore, this band does not have as much interference or suffer the effects of multipath fading that is common on the 2.4 GHz microwave band.

As for what is short range, it varies. It can be just a few feet or many hundreds of feet. If you have a clear line of site between transmit and receive antennas with a gain antenna, you can probably extend that to a few miles. Most applications typically involve distances of less than 100 feet. The transmit power is usually low. A power level of zero dBm or one milliwatt is common, but you can get units with up to 100 mW of power if you need a longer range.

The key to ensuring that your wireless installation will work is to do some basic math and calculate the path loss and the range given the specifications of the devices you are using.

Path loss can be calculated with the formula that follows. Just plug in the frequency of operation and the range, and the result will be a path loss in dB.

$$\text{Path loss in dB} = 37 + 20 \log f + 20 \log d$$

The frequency f is in MHz and the range or distance is in miles. If the range is in feet, divide the number of feet by 5,280 to get miles. You can also use this formula:

$$\text{Path loss in dB} = 20 \log (4\pi/\lambda) + 20 \log d$$

Here the wavelength is in meters and the distance d is in meters.

Assume a frequency of 915 MHz and a range of 100 feet. That is 0.018939 miles. Use your scientific calculator to compute this.

dB = 37 + 20 log (915) + 20 log(.018939) = 37 + 59.23 – 34.45 = 61.79 dB

Note: The log of fraction gives a negative number that is the reason for the -34.45 number.

Next, find out what the transmit power is from the module specs. Power is usually stated in terms of dBm or decibels referenced to one milliwatt. Assume 2 mW or 3 dBm. Add the transmit power to the path loss (algebraically) to get the amount of power the receiver will receive at the distance you used.

Received power = 3 - 61.79 = -58.79 dBm

Finally, compare that to the receiver sensitivity figure usually given in –dBm. The larger the number, the better the sensitivity. A sensitivity of -100 dBm means the receiver can detect a signal that small. A sensitivity of -80 dBm is not as good as -100 dBm. That means that in terms of power, -80 dBm is greater than -100 dBm. So, if the received power is greater than the sensitivity figure, the signal will be received. Assume a receiver sensitivity of -70 dBm. Since the received power is greater than the sensitivity figure, you will have a good link.

Incidentally, this calculation assumes basic isotropic antennas with a gain of one. If you use a dipole or ground plane, the real power gain is 1.64.

THE WIRELESS MODULES

The wireless devices I bought were part of a whole package called the Master Evaluation/Development System, specifically the Linx Technologies MDEV-HP3-PPS-USB. It comes with two development boards: one for transmit and the other for receive. It also has two each of the transmitter modules (TXM-900-HP3-xxx) and receiver modules (RXM-900-HP3-xxx). The development boards have a USB port on them but you can also get a version for RS-232. Cables and programming software is included. **Figure 1** shows the whole package.

Figure 2 shows the transmit block diagram. It uses a PLL frequency synthesizer programmed by an internal microcontroller for any of the 100 channels in the 902-928 MHz range. A 12 MHz crystal sets the precision and frequency increment at 250 kHz. You can select any of the existing frequencies by programming via the PC, or any of eight frequencies that can be set with a DIP switch on the transmitter development board. The PLL and its VCO act as a frequency multiplier to increase the output frequency into the 902-928 MHz range. Then, a power amplifier boosts the output signal to 0 dBm or in the -3 to +3 dBm range. An output filter gets rid of any pesky harmonics.

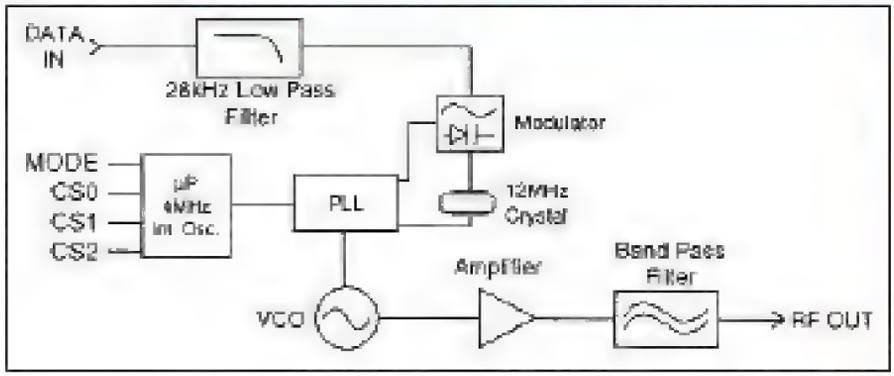
The modulation is FSK and you can achieve a data rate up to about 56 kbps. A 28 kHz low pass filter on the data input filters the binary serial data to help restrict the harmonics and the sidebands, and to keep the frequency deviation down to less than 115 kHz. Incidentally, you can also modulate the transmitter with analog signals up to 28 kHz.

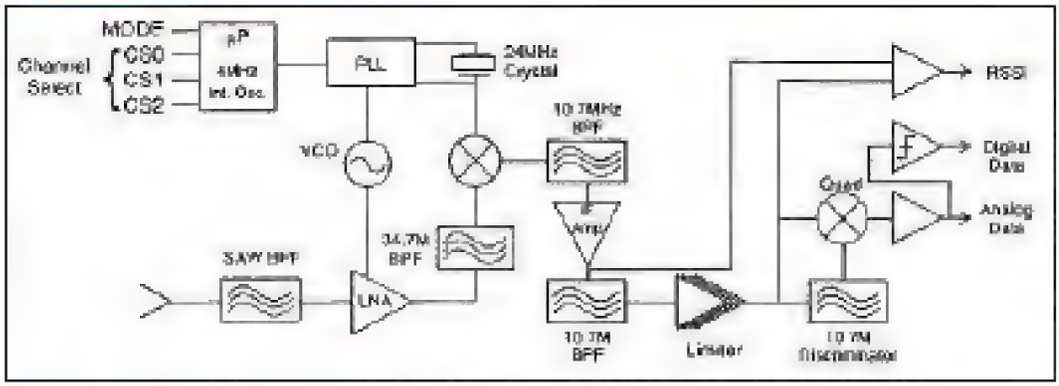
■ FIGURE 1. The Linx Technologies MDEV-HP3-PPS-USB wireless development system. The transmit board is on the left; the receive board is on the right. The transmitter module is on the left and the receive module is on the right. The modules plug into the boards to complete the system. Note the vertical antennas on the right of each board.

You can program the transmitter frequency using the software and USB port on the development board but I just used the DIP switch on the development board. This switch feeds an on-board encoder chip ENC-LS001. It takes the three-bit input code and serializes it into a simple protocol with start and stop bits that the transmitter sends out to the receiver. This eliminates the need for you to create a complex protocol, although you can do that if you want to.

The receiver block diagram is shown in **Figure 3**. It is a superheterodyne using a PLL synthesizer for tuning. The input from the antenna is frequency restricted with a SAW (surface acoustic wave) filter and applied to a low noise (RF) amplifier (LNA). The LNA block also includes a mixer that mixes the incoming signal with a signal from the frequency synthesizer to produce a first intermediate frequency (IF) of 34.7 MHz. The signal is filtered, then sent to another mixer along with a 24 MHz signal from

■ FIGURE 2. The Linx Technologies TXM-900-HP3-xxx transmitter module block diagram. *(Courtesy Linx Technologies.)*





■ FIGURE 3. The Linx Technologies RXM-900-HP3-xxx receiver module block diagram. *(Courtesy Linx Technologies.)*

the crystal oscillator. The mixer output is a 10.7 MHz second intermediate frequency (IF) signal that is filtered — limited to remove any amplitude variations — and sent to the quadrature demodulator where the signals are recovered. A slicer/shaper cleans up the digital signal.

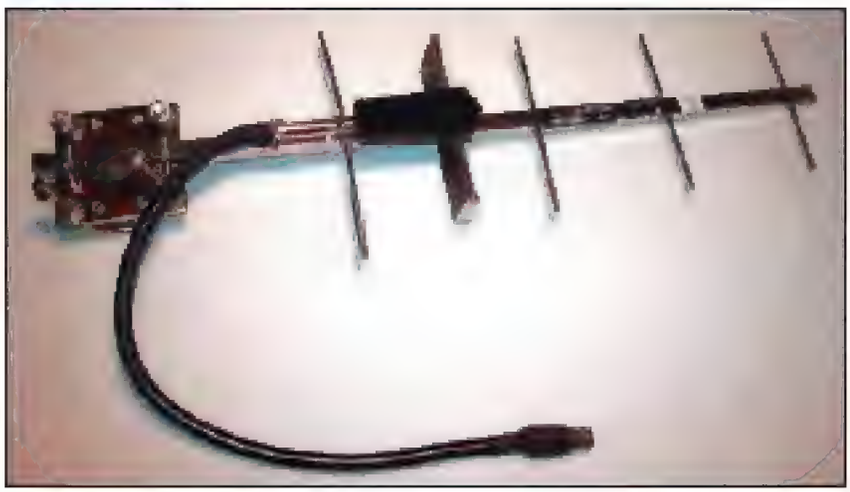
A neat feature of this module is the received signal strength indication (RSSI) circuit. It is a calibrated output that indicates the level of the received signal. It generates a DC signal in the one to three volts range, corresponding to input power levels in the -40 to -110 dBm range. Using this feature lets you actually measure the signal level being picked up.

DEMONSTRATING THE MODULES

To get the boards ready for use, you plug in the transmit and receive modules, screw on the antennas, and install a nine volt battery in each. The battery drives a five volt regulator that supplies power to the modules.

Once you set the frequency on both the transmit and receive boards, are can demo them. Turn on the power switches. Then, press the yellow button on the transmit board that will sound the buzzer on the receive board with a beeping tone. The red transmit button causes a relay on the receive board to close. You can hear it click.

■ FIGURE 4. The Antenna Factor ANT-916-YG5-N Yagi antenna. It has a 50 ohm cable and N-connector. I had to buy two extra cables with different connectors to match up with the SMA connector on the transmit and receive boards.



The relay contacts have connectors on the receive board so you can hook them up to control some other device like a light or motor. The relay contacts can handle as much as five amps up to 30 volts DC or 120 volts AC.

As a next step, you can take the boards outside and test the range. I took the boards out in the street with my wife and tried to estimate the maximum range. Keep the line of site path clear to get the best results. You should easily get several hundred feet. I got 300 feet before a hill cut my line of sight path. (I live in central Texas where it is called the hill country.)

For further experimentation, you can put obstacles between the transmitter and receiver. Walls, trees, cars, whatever. The units still communicate, but the obstacles add considerable extra attenuation to the path thereby shortening the range.

One other demo you can do is check out the RSSI voltage. Get a digital or analog multimeter and connect it up to the RSSI pins on the receiver board. Turn on the units and measure the RSSI voltage over a decent range. The output voltage is roughly linear from about 1.2 volts DC at -110 dBm received power to 2.7 volts at -40 dBm. You could calculate the received power using the formula above, then attempt to verify it with the RSSI reading for a given power and distance. Incidentally, the transmit power is nominally 0 dBm or 1 mW. The specs indicate a possible range from -3 dBm to + 3 dBm so any errors will probably be in transmit power or range measurements.

One final thing I did was to buy an accessory five-element Yagi antenna (**Figure 4**). The antenna is made by Antenna Factor, and is available through Linx. It has a gain of 9 dBi (isotropic gain). It gets that gain by focusing the power in one direction so the effect is that of a transmitter power boost or improved receiver sensitivity. I used the antenna on the receiver. The effect was to greatly increase the range of transmission by a factor of three or more. Not bad. You can note that change on the RSSI reading.

That is all the time I had for the demos, but I do plan to do more. I particularly want to plot the Yagi antenna pattern by using the RSSI readings as I rotate the antenna horizontally. Should be interesting.

Wireless is fun to play with, but I do admit it is also frustrating at times. Things don't always work as they should, as they seem, or as you want. Mostly, this is due to obstacles in the path like trees or walls, multipath signals developed from nearby reflecting bodies (cars, water tower, etc.), or you personally being too close to either the receive or transmit antennas. So, you need to experiment for best results. Once everything is set up correctly, the communications link is remarkably reliable, almost as good as a wire. **NV**

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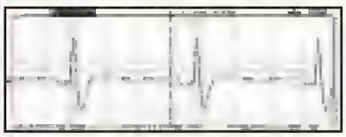
Use the ECG1C to astound your physician with your knowledge of ECG/EKG systems. Enjoy learning about the inner workings of the heart while, at the same time, covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The three probe wire pick-ups allow for easy application and experimentation without the cumbersome harness normally associated with ECG monitors.

The documentation with ECG1C covers everything from the circuit description of the kit to the circuit description of the heart! Multiple "beat" indicators include a bright front panel LED that flashes with the actions of the heart along with an adjustable level audio speaker output that supports both mono and stereo hook-ups. In addition a monitor output is provided to connect to any standard oscilloscope to view the traditional style ECG/EKG waveforms just like you see on ER... or in the ER! See the display above? That's one of our engineers, hooked up to the ECG1C after an engineering meeting!



The fully adjustable gain control on the front panel allows the user to custom tune the differential signal picked up by the probes giving you a perfect reading and display every time! 10 hospital grade re-usable probe patches are included together with the matching custom case set shown. Additional patches are available in 10-packs.

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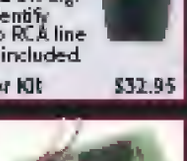
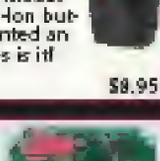
Mini LED Light Chaser



This little kit flashes six high intensity LEDs sequentially in order. Just like the K8030Z to the right does with incandescent lights. Makes a great mini attention getter for signs, model trains, and even RC cars. Runs on a standard 9V battery.

MK173 Mini LED Light Chaser Kit $15.95

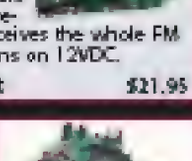
Running Light Controller



Controls and powers 4 incandescent lights so they appear to "travel" back and forth (Like the hood on KITT!). Great for the dance floor or promotional material attention getters, exhibits, or shows. Runs on 112-240VAC.

K8032 4-Channel Running Light Kit $38.95

High Power LED Driver



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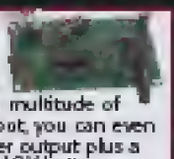
Digital Voice Changer



This voice changer kit is a riot! Just like the expensive units you hear the DJ's use, it changes your voice with a multitude of effects! You can sound just like a robot, you can even ad vibrato to your voice! 1.5W speaker output plus a line level output! Runs on a standard 9V battery.

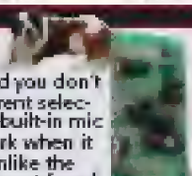
MK171 Voice Changer Kit $14.95

Steam Engine & Whistle

Simulates the sound of a vintage steam engine locomotive and whistle! Also provides variable "engine speed" as well as volume, and at the touch of a button the steam whistle blows! Includes speaker. Runs on a standard 9V battery.

MK134 Steam Engine & Whistle Kit $11.95

Electronic Watch Dog



A barking dog on a PC board! And you don't have to feed it! Generates 2 different selectable barking dog sounds. Plus a built-in mic senses noise and can be set to bark when it hears it! Adjustable sensitivity! Unlike the Saint, eats 2-9VAC or 9-12VDC, it's not fussy!

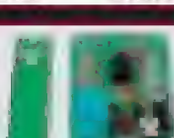
K2655 Electronic Watch Dog Kit $39.95

Laser Trip Sensor Alarm

True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1 Laser Trip Sensor Alarm Kit $29.95

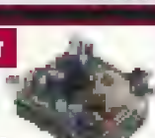
Liquid Level Controller



Not just an alarm, but gives you a LED display of low, middle, or high levels! You can also set it to sound an alarm at the high or low condition. Provides a 2A 240VAC rated relay output. Runs on 12-14VAC or 16-18VDC.

K2639 Liquid Level Controller Kit $23.95

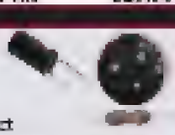
Stereo Ear Super Amplifier



Ultra high gain amp boosts audio 50 times and it does it in stereo with its dual directional stereo microphones! Just plug in your standard earphone or headset and point towards the source. Incredible gain and perfect stereo separation!

MK136 Stereo Ear Amp Kit $9.95

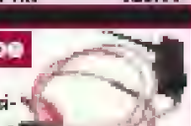
Electret Condenser Mic



This extremely sensitive 3/8" mic has a built-in FET preamplifier! It's a great replacement mic, or a perfect answer to add a mic to your project. Powered by 3-15VDC, and we even include coupling cap and a current limiting resistor! Extremely popular!

MC1 Mini Electret Condenser Mic Kit $3.95

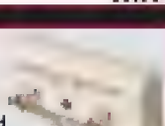
Sniff-it RF Detector Probe



Measure RF with your standard DMM or VOM! This extremely sensitive RF detector probe connects to any voltmeter and allows you to measure RF from 100kHz to over 1GHz! So sensitive it can be used as a RF field strength meter!

RF1 Sniff-it RF Detector Probe Kit $27.95

Broadband RF Preamp



Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Assmb.

PR2 Broadband RF Preamp $69.95

Vintage Battery Eliminator

Collectors come across some great deals on antique battery-powered radios, but how to power them is a real problem. Many classic radios operated on batteries only, and in many cases a series of three batteries for each radio were required!

The new ABCE1 Battery Eliminator gives you an easy way to replace all these batteries with a simple household AC power connection and resurrect your vintage antique radios! Provides "A" filiment, "B" plate, and "C" control grid supplies, which are all isolated from each other. Complete with aluminum case. Runs on 110-240VAC.

ABCE1	Vintage Radio Battery Elim Kit	$199.95

Digital Message System

The third generation of Ramsey digital voice storage kits! We started with the latest digital voice storage technology. It provides up to 8 minutes of digital storage at a frequency response up to 3.5 KHz. (Total message time and frequency response is dependant on selected internal sampling rate.) Once recorded, messages are available for playback on-demand or automatic continuous looping. Standard RCA unbalanced line level output is provided for easy connection to any amplifier, amplified speaker, mixer, or sound system. In addition, a standard 4-8 ohm speaker output is provided to directly drive a monitor speaker. Can be remote controlled via 3-wire BCD with our interface options. Check www.ramseykits.com for all options!

DVMS8	Digital Voice Message 8Ch Kit	$99.95
DVMS8WT	Assembled DVMS8	$149.95

Ultimate 555 Timers

This new series builds on the classic UT5 kit, but takes it to a whole new level! You can configure it on the fly with easy-to-use jumper settings, drive relays, and directly interface all timer functions with onboard controls or external signals.

UT5A UT5AS

All connections are easily made though terminal blocks. Plus, we've replaced the ceramic capacitor of other timer kits with a Mylar capacitor which keeps your timings stable over a much wider range of voltages! Available in through hole or surface mount versions! Visit www.ramseykits.com for version details.

UT5A	Through Hole 555 Timer/Osc Kit	$24.95
UT5AS	SMT 555 Timer/Osc Kit	$26.95

Passive Aircraft Monitor

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

ABM1	Passive Aircraft Receiver Kit	$89.95

Voice Activated Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.

VS1	Voice Switch Kit	$9.95

OBDII CarChip Pro

The incredible OBDII plug-in monitor that has everyone talking! Once plugged into your vehicle it monitors up to 300 hours of trip data, from speed, braking, acceleration, RPM and a whole lot more. Reads and resets your check engine light, and more!

8226	CarChip Pro OBDII Monitor-Asmb	$99.95

RF Preamplifier

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7	RF Preamp Kit	$19.95

Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.

TS1	Touch Switch Kit	$9.95

Doppler Direction Finder

Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.

DDF1	Doppler Direction Finder Kit	$169.95

Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

MB1	Mad Blaster Warble Alarm Kit	$9.95

Laser Light Show

Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

LLS1	Laser Light Show Kit	$49.95

Retro Nixie Tube Clock

Genuine Nixie tubes popular in the 50's brought back in one of the neatest digital clocks around today! Hand made teak maple base. 12/24 hour format, soft fade-out, auto-dim, and a crystal time base at 20ppm! Tube kits also available.

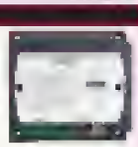
IN14TM	Teak Maple Nixie Clock Kit	$329.95

Water Sensor Alarm

This little $7 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump)! When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.

MK108	Water Sensor Alarm Kit	$6.95

USB DMX Interface



Control DMX fixtures with your PC via USB! Controls up to 512 DMX channels each with 256 different levels! Uses standard XLR cables. Multiple fixtures can be simply daisy chained. Includes Light Player software for easy control. Runs on USB or 9V power.

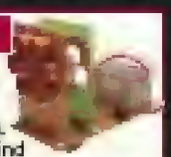
K8062	USB DMX Interface Controller Kit	$67.95

HV Plasma Generator

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20KHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

PG13	HV Plasma Generator Kit	$64.95

Air Blasting Ion Generator



Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

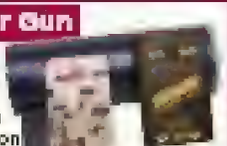
IG7	Ion Generator Kit	$64.95

Tickle-Stick Shocker

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk. "Hey, I told you not to touch!" Runs on 3-6 VDC.

TS4	Tickle Stick Kit	$12.95

Speedy Speed Radar Gun



Our famous *Speedy* radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. You supply two coffee cans! Runs on 12VDC or our AC125 supply.

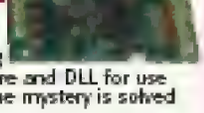
SG7	Speed Radar Gun Kit	$69.95

Tri-Field Meter Kit

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.

TFM3C	Tri-Field Meter Kit	$74.95

USB Experimenter's Kit



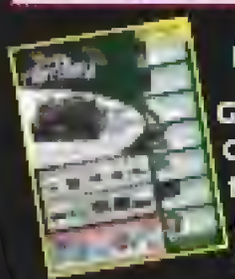
Get hands-on experience developing USB interfaces! 5 digital inputs, 8 digital outputs, 2 analog I/O's! Includes diagnostic software and DLL for use with Windows based systems. The mystery is solved with this kit!

K8055	USB Experimenter's Kit	$49.95

3-in-1 Multifunction Lab

The handiest item for your bench! Includes a RoHS compliant temp controlled soldering station, digital multimeter, and a regulated lab power supply! All in one small unit for your bench! It can't beat!

LAB1U	3-In1 Multifunction Solder Lab	$129.95



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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ Blinking Tail Light
- ✓ Geiger Counter
- ✓ Mailbag

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. **Send all questions and comments to:** Q&A@nutsvolts.com

LOW VOLTAGE WARNING

Q I am looking for a low voltage warning system for an antique Delco light plant. The Delco light plant has two 12 volt and one eight volt lead acid batteries in series for a total of 32 VDC. As the voltage drops from running the lights, you start the plant and charge the batteries back up. The problem is if you let the voltage drop too low, you don't have enough battery power to start the plant again. I would like a warning system to incorporate an LED strip and buzzer. Fully charged, all LEDs are on and the buzzer is off. As the battery voltage drops, each LED goes off until they are all off at which time the buzzer comes on (approximately 28 volts) to get your attention. I would like the voltage points to be adjustable by replacing resistors.

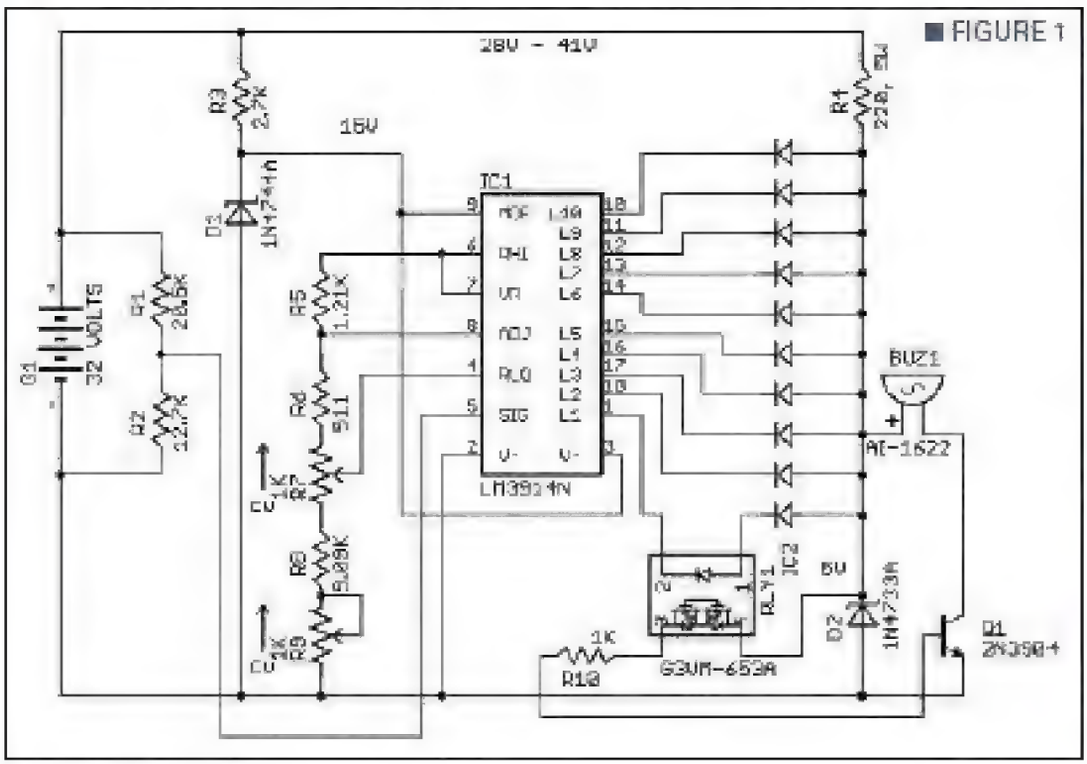
— Bill Blackburn

A The LM3914 bar graph driver was made for this application; it has the voltage divider, comparators, and current source output to light 10 LEDs. The resistors are not adjustable but you can adjust the upper and lower voltage of the display. The LM3914 has linear increments, but if you prefer, the LM3915 has logarithmic increments.

The battery has 16 cells of nominal 2.1 volts, giving 33.6 volts nominal; the full charge voltage will be 36.8 volts. At 28 volts, the battery is fully discharged with 1.75 volts per cell. In **Figure 1**, resistors R1 and R2 divide the battery voltage down to 12.6 volts nominal and 10.5 volts at full discharge.

Pins 7 and 8 of IC1 comprise an adjustable voltage regulator. The high end of the internal voltage divider is connected to the output (pin 7) and the low end is connected to R7. R9 is first adjusted to give 12.6 volts at pin 7, and then R7 is adjusted for 10.5 volts at pin 4. When the battery is fully charged, the voltage at pin 5 will be 12.6 volts or higher, and all the LEDs will be lit. When the battery falls below 28 volts, all the LEDs will be out and the buzzer will sound. The solid-state relay is normally closed when not energized and open when energized. **Figure 2** is the parts list.

■ FIGURE 1



ENERGY COMPUTATION

Q I am trying to find the energy in an inductor but my math is obviously wrong. I won't be offended if I find that I have been taking a completely

ridiculous approach. I used real parts that I had. That's where the values came from. The first inductor allows .0853 amps to flow when 17.00 volts RMS @ 60 Hz is applied through a Fluke 27 (a 1% digital meter).

R = E/I
XI = 17/.0853
XI =199.3 ohms
XI = 2PiFL
XI/(2PiF) = L
L = .529H

I set the current at .04 amps with a constant current (to ground) circuit.

1 volt/1 henry = 1 amp/1 second
1V/.529H = .04A/time
time = .02116 seconds

If the current rise in an inductor is a ramp, the average current is .02 amps; .02 amps x .02116 seconds = 423 uamp-seconds involved in the magnetic field.

When the constant current is shut off, the inductor sends its energy through a fast diode (500 nS) to a 0.1 µF capacitor.

(1 amp x 1 second)/1 farad = 1 volt
(.02 amps x .02116 seconds)/0.1 µF = 4230 volts

This is not what the scope shows, by quite a bit.

Second, I have a 24 volt DC relay that uses .0425 amps (activated) and has 565 ohms of DC resistance. This relay actually gets used in an air conditioner and I design controllers for air conditioners. This relay has significant resistance. I would like to know how that affects the equations; 12.03 volts @ 60 Hz sends 10.00 mA through the coil without making the contacts close. This suggests 2.82 H, unlatched. When powered from a filtered DC source, the ripple is .64V p-p and the AC current is .20 mA. If the VRMS of this ramp-looking wave is (V p-p)/4,

Z = E/I
Z = .16/.0002
Z^2 - R^2 + XI^2
XI =800 @ 120 Hz
L = 1.06H in the latched condition.

How much voltage will be developed into a capacitor that is connected from the collector to ground when the transistor is turned off? This depends on the size of the capacitor, so the answer must be an equation.

Third, a 24 VAC relay has 10.5 ohms of DC resistance and allows .258 amps to flow when 24 VAC is applied (60Hz): Z = 93 L = .245H.

When the relay is on, .258 amps RMS is flowing. When the triac turns off at zero volts of the AC line, the current is at its peak — .365 amps (give or take a bit for the DC resistance). How much voltage will try to get through the triac if it is in parallel with a capacitor?

— Chuck

A You did not measure the resistance of the inductor, so if that was significant, the inductance calculated would be higher than actual. Assuming that the resistance is not significant, your calculations are okay up to the point of calculating the voltage on the capacitor. I don't know why you used the average current, but you got the right answer: 423 X 10^-6. I would have used the peak current in the equation: E=1/2LI^2.

E = 1/2*.529*(.04)^2 = 423 X 10^-6 (not sure what the units are; Joules?)

Your final calculation of voltage is the problem. The equation assumes constant current and the time is the discharge time. You used the charge time, and the discharge current is not constant. The equation to use is:

E = 1/2CV^2

Solving for V: V = (2*E/C)^0.5 = (2*423/0.1)^0.5 = 92V

In your second problem, I would expect the latched inductance to be higher than the unlatched inductance. Measuring the AC current while holding the contacts closed would give a better measurement. Having found the inductance (your calculations are okay), calculate the voltage using the relation: E=1/2LI^2 = 1/2CV^2 and solve for V:

V = I*(L/C)^0.5 where I is the current flowing when the circuit is interrupted.

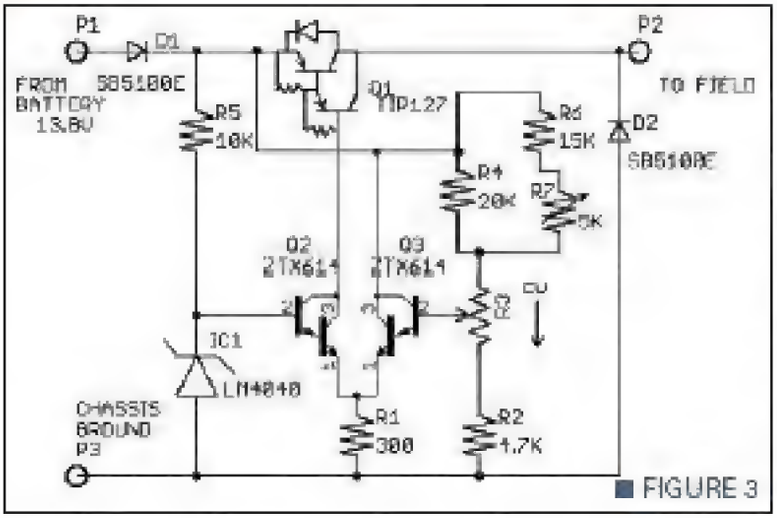
In your case, and using C = 0.1uF, V = 138V.

This solution neglects the resistance, so the calculated voltage will be higher than actually experienced. If the resistance is low, the energy will bounce back and forth between the inductor and capacitor, getting smaller as the energy is used up in the resistor. At some value of resistance (critical damping), the current will just decay to zero. We define a quality factor: Q = XI/R. Critical damping is when Q = 1/2. Q less than 1/2 will not have oscillation and is where you want to be. If the inductor has low resistance, you may want to add resistance in

BATTERY MONITOR PARTS LIST ■ FIGURE 2

PART	DESCRIPTION	PART #
R1	20.5K, 1%, 1/4W	271-20.5K-RC
R2	12.7K, 1%, 1/4W	271-12.7K-RC
R3	2.7K, 5%, 1/4W	291-2.7K-RC
R4	220, 5%, 5W	286-220-RC
R5	1.21K, 1%, 1/4W	271-1.21K-RC
R6	511, 1%, 1/4W	271-511-RC
R7, R9	1K TRIMPOT, CERMET, 1/4W	81-PV37W102C01B00
R8	9.09K, 1%, 1/4W	271-9.09K-RC
R10	1K, 5%, 1/4W	291-1K-RC
D1	15V ZENER, 1W, 5%	512-1N4744A
D2	5V ZENER, 1W, 5%	512-1N4733A
Q1	GP NPN, 2N3904	512-2N3904TA
IC1	BAR GRAPH DISPLAY DRIVER	300008 JAMECO
IC2	LED BAR GRAPH DISPLAY	859-LTA-1000HR
BUZ1	5V PIEZO BUZZER, 85 dB	665-AI-1622WT5VR
RLY1	SOLID-STATE, 350V, 50 OHMS, NC	653-G3VM-353A1

MOUSER.COM PART NUMBERS EXCEPT AS NOTED



■ FIGURE 3

series with the capacitor. Xl in this case is calculated using the frequency F = 1/2Pi(LC)^.5.

I simulated the circuit and got a peak voltage of 140V, so it appears that there is not much energy lost in the resistance.

In your third case, the calculated voltage is 571 volts with C = 0.1 µF. My simulation shows 595V but if I put 620 ohms in series with the capacitor, the peak voltage is 500 volts and there is no ringing. I didn't calculate the Q but it should be about 1/2.

ALTERNATOR REGULATOR

Q I loved your circuit for an automobile generator voltage regulator from October '09. Do you have something similar for an alternator? Mine is an old General Motors Delco-Remy alternator (1967 Pontiac) with an external vibrating relay type regulator. One side of the alternator field coil is grounded to the frame and the other comes out to the F terminal. There is also an unused R terminal which was to be used with an idiot light, but this car has an ammeter.

I have a friend who would like to use such a circuit to charge a 24 volt battery, so any modifications to make the same circuit work in a 24 volt setting would be welcome.

— Mike Watford

A I know I designed this before, but I didn't put the schematic where I could find it so this one is new. In **Figure 3**, the transistors and diodes are rated to 100 volts in order to survive transients of the automotive system. D1 protects against reverse voltage and D2 catches the backswing of the field inductance when Q1 turns off. I used Darlington transistors to keep the power in the control circuit low. IC1 is a four volt (4.096V nominal) shunt reference. R7 is a thermistor to temperature-compensate the charger. My battery manual recommends 2.5 to 3 millivolts per cell; this is intended to do that. You will need to adjust R3 to get 13.8 volts at the battery. One way to do this on the bench is to apply 13.8 VDC to P1 and connect a 12 volt light bulb to the field output. Adjust R3 so the light just goes out. I have used TO-220 transistors in this application without a heatsink, but a small heatsink would be more reliable. If you put the circuit in an aluminum box, use the box as the heatsink (but insulate the box). I used a RadioShack plastic box with an aluminum cover.

To use this circuit in a 24 volt system, double R3, R4, R6, and R7. **Figure 4** is the parts list.

ALTERNATOR REGULATOR PARTS LIST ■ FIGURE 4

PART	DESCRIPTION	PKG	MOUSER PART #
D1, D2	DIODE, 100V, 5A, SCHOTTKY	DO-15	750-SB5100E-G
Q1	PNP DARLINGTON, 100V, 5A	TO-220	511-TIP127
Q2, Q3	NPN,DARLINGTON, 100V, 800 mA	TO-226	512-ZTX614
D3	4.096V SHUNT REGULATOR	TO-92	595-LM4040D41ILP
R3	1K TRIMPOT	3266W	652-3266W-1-102LF
R1	300 OHMS, 1/4W, 1%, METAL FILM	AXIAL	271-300-RC
R2	4.7K, 1/4W, 1%, METAL FILM	AXIAL	271-4.7K-RC
R4	20K, 1/4W, 1%, METAL FILM	AXIAL	271-20K-RC
R5	10K, 1/4W, 1%, METAL FILM	AXIAL	271-10K-RC
R6	15K, 1/4W, 1%, METAL FILM	AXIAL	271-15K-RC
R7	5K THERMISTOR	RADIAL	871-B57540G502F

BLINKING TAIL LIGHT

Q If you have ever been hit in the rear by a vehicle because the driver was asleep, playing with a cell phone, or whatever, it doesn't take too much to make you ill at ease with traffic closing in on you. I speak from experience (1951, 1992, and 1997).

A low frequency flasher and driver inserted right after the brake light switch should get the attention of the person closing in on your rear-end even with text messaging, cell phones, and loud music. Do you think their mind could process a flashing red brake light in addition? What ideas do you have for this?

— Bob Haskett

A I have my doubts that flashing brake lights will be effective, and you should check with local ordinances that they are legal. In any system that I am familiar with, voltage is applied through the brake switch to the lights which are grounded. To use this circuit, you will need to cut the brake wire and splice in the circuit and ground.

In the circuit in **Figure 5**, the transistors are rated at 100 volts to survive the automotive environment. Some vehicles have five brake lights, so I designed for 10 amps current. Q1 will dissipate 20 watts in the worst case and R1 needs a heatsink for 10 watts, so a 30 watt heatsink is required. For a 50 deg C rise above ambient, a heatsink rated at 1.7 deg C/W should be used. **Figure 6** is the parts list.

I think a 4 Hz blink rate would be optimum and will use a hysteresis oscillator. The CD4093 Schmitt-trigger

gate has 0.9 volts hysteresis, according to the datasheet so I computed the R-C values using the relation: dV/dt = I/C. In this case, the voltage on the capacitor will ramp up and down in 0.25 seconds (4 Hz period).

dV = 0.9V
dT = 0.125 sec
Set I = 0.1 mA = 3V/R3, therefore R3 = 30K (3V is 1/2 the supply voltage).
C = IdT/dV = 0.1 mA*0.125S/0.9V = .0139 mF; 15 µF is a standard and close enough. I chose a tantalum cap for low leakage and temperature stability.

I chose the 6.2 volt zener because it has a sharp knee and will hold a constant voltage over a wide current range. The five volt zener has high internal resistance and is not as stable. For improved temperature stability, you can put a silicon diode in series with the zener. The two temperature coefficients approximately cancel.

MAGNETIC QUESTIONS

Q 1. In regards to *N & V* March '10, page 30: What size wire do I use to wind 82.5 or 87.2 turns on the core of the RS 273-104? Can I round it off to the nearest turn?

2. Using the same RS 273-104 core, I need 2 IF transformers for 455 kHz. Can I do this on this core and how many turns will it need? IF transformers are getting hard to find and costly.

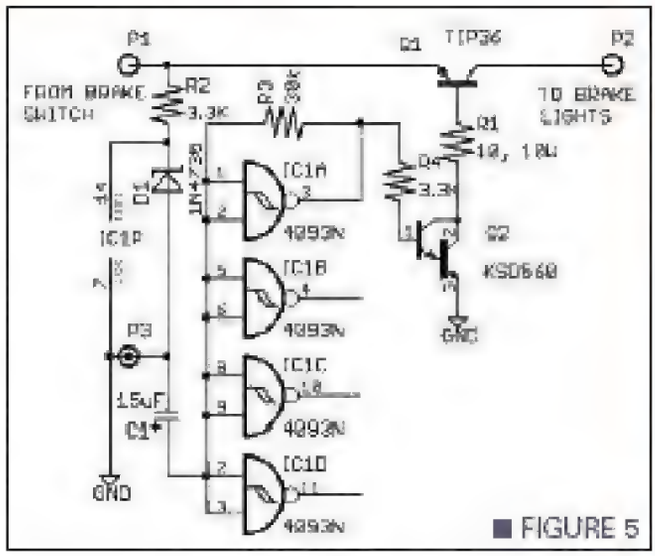
3. Again, using the same 273-104 core, I need a ratio detector or discriminator transformer. The driving tube will be 6BN11 or 6BW11. The secondary center tap in the middle and the two opposite ends go to the deflection plates of a 6AR8A.

— Craig Kendrick Sellen

A 1. Wire size does not matter, as long as it fits in the opening. Keeping in mind that the inductance varies as the square of the number of turns, you may want to round up or down. Without measuring the inductance, it is only approximate anyway; #16 wire or smaller will fit.

2. I rather doubt that this core will be good at 455 kHz and there is no data on it. You will be better off to salvage a transformer from an AM radio.

3. I don't know how the 6AR8A discriminator works — that is up to you — but the transformer is shown in **Figure 7**. R1 simulates the 6BN11 plate resistance, and R2 and R3 load the transformer at resonance to widen the bandwidth. I did not simulate the resistance of the coil; I don't think it will be significant. There are three identical coils of 360 uH each. Each one has 45 turns of #20 wire or smaller (#16 wire would take up all the opening with no room for insulation). I assumed that the tuning cap would be 365 pF variable as found in most AM radios.



■ FIGURE 5

GEIGER COUNTER

Q Many months ago, I saw an article in *Nuts & Volts* (I think) about building a Geiger counter. I've searched the past several years' worth of issues but haven't found it. Either I haven't found the right issue or it was someplace else. Any ideas about the issue or how to build one?

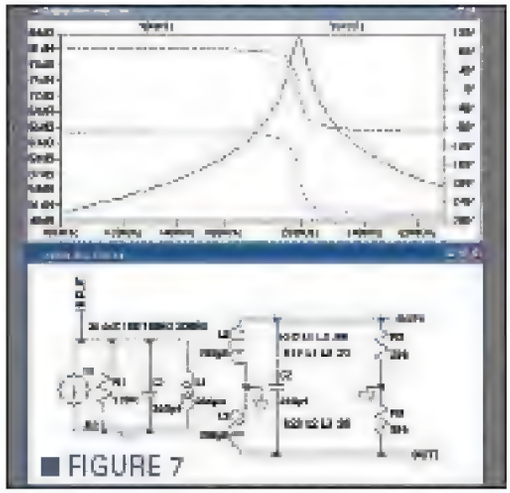
I have an old "tube type" unit that doesn't work — even after I replaced the 67 1/2 volt batteries with a bench supply. I've got a nice metal box, display meter, switches, etc., and a GM tube in a housing. I'd like to make something of this thing.

— Duane Haines

A The article that you remember was in March '05 (page 36) and May '05 (page 50). You can easily search back issues on the *Nuts & Volts* website (**www.nutsvolts.com**) and click on the digital issue search (**www.nutsvolts.com/search-digital.php**). If you want to repair the Geiger counter, first check the tubes. If you

FLASHING BRAKE LIGHT PARTS LIST ■ FIGURE 6

PART	DESCRIPTION	PKG	MOUSER PART #
Q1	PNP, 100V, 25A	TO-247	511-TIP36C
Q2	NPN DARLINGTON, 100V, 5A	TO-220	512-KSD660
IC1	QUAD NAND SCHMITT	DIP-14	595-CD4093BE
D1	6.2V ZENER, 1W	DO-41	512-1N4736A
C1	15 µF, 20%, 10V	RADIAL	74-199D16V15
R1	10 OHMS, 10W, 5%	AXIAL	71-RH10-10
R2, R4	3.3K, 1/4W, 5%	AXIAL	291-3.3K-RC
R3	22K, 1/4W, 5%	AXIAL	291-22K-RC
HEATSINK	50 DEG C/30W (1.7 DEG C/W)		558-HS172


■ FIGURE 7

MAILBAG

Dear Russell:

Re: LED Laser, Jan '10, page 22. I may be a little late on this, but while scanning through the Jan issue of *Nuts & Volts* I was alarmed by the first question in your column. The description of the "IR LED laser" bought on eBay was disturbing (as was the intended use, of "cutting some plastics").

A laser is a laser — not an LED — and can be extremely dangerous. A 30W IR laser (which is probably in the 808 nm range) can easily cause permanent damage to your eyes in an instant and should be operated with great care. Likewise, laser ablation (and burning, which would certainly occur with this laser) of certain plastics (such as polycarbonate) can release harmful vapors.

A word of warning should be passed along to the person who asked the question — and maybe a mention of the dangers should be included in any future answers. I would hate to see a hobbyist damage his or her eyesight or poison him/herself as a result of playing around with a very cool but dangerous laser.

— Chris Fredricksen

Response: Thanks for the feedback, Chris. A word from the wise is always good.

Dear Russell:

Re: Large Clock, Jan '10, page 20. From my first glance at the code, there seems to be several errors.

1) One would have to hold the setting buttons in for possibly a full five minutes if the code was in the five Pause 60000 delay loops (which it essentially always is) when you pushed them. BAD; impossible to really set.

Probably the easiest fix would be to use a one second pause loop nested in several counters so one could check for pushbutton access after each one second delay.

2) The incrementing code ... Let M=M+H in your main loop which is supposed to set just the minutes; it will also increment the hours since you already have the H in the M variable. Each loop will have H again. BAD.

I would suggest using a separate variable — say T — to combine the total minutes and hours, and present this to the display.

```
Let T=M+H
Let PORTC = T
```

3) Your minute total of 112 is wrong. Should be 12 times the 16 = 192. So the code should look something like:

```
FOR H=1 TO 12
'loop for 12 hours
FOR M=16 TO 192
'loop for 12 five minutes
'intervals
        LET T=M+H
        LET PORTC =  T
        FOR X=1 TO 360
' delay 5 minutes...360 one
' second loops.
```

use your pushbutton checking code with some changes to use T=M+H and just clean up the button checking.

```
            PAUSE 1000
wait one second
          NEXT X
       NEXT M
    NEXT H
```

Pushbutton checking code should increment either M or H and then put them together in T, and display:

```
SETMIN:
     M=M+16
     T=M + H
     PORTC = T
     IF PORTA PIN 0 = 1
THEN  GOTO  SETMIN
     RETURN
```

I think the whole thing needs a major rewrite.

— Evan Wasserman

Response: Thanks for taking the time to analyze my code, Evan. I surely would have seen those errors if I had actually run the program. Mea culpa once again.

More feedback on the large clock program from Eric Fulton.

Dear Russell:

I programmed the 28X2 chip with your program, with a few changes. It runs on the edit program on my computer.

As I'm new to programming, I hope it works. I added a magnetic switch to reset at 12:00 o'clock twice each day.

I added a set frequency M4 command; I changed the code of line 14 to: for M = 16 to 192; added LET M=M-H before next M; added GOTO for the time correction after next H; and added a sub-routine for the correction.

The 28X2 did not use port commands so I changed them to pin commands. Breadboarded it and it ran.

I think this program will work. I had no idea of how to proceed until you helped. Thanks again.

— Eric L. Fulton

Response: Thanks for the feedback, but I think you should incorporate more of Eric Wasserman's suggestions.

Dear Russell:

Re: High Current LED Driver, Jan '10, page 22:

Thanks not only for your excellent article (I have already bought the parts), but also for the feedback. Such warnings cannot be stressed enough. Some of the precautions I take are:

1. I do not experiment without my laser protection goggles on.

2. Absolutely nobody can be in my vicinity when experimenting with a laser.

3. The laser is fixed on a table (not lying around so it can topple), pointing to where it can do little harm (non-reflective surface).

4. I use my webcam or digital video cam to look for output.

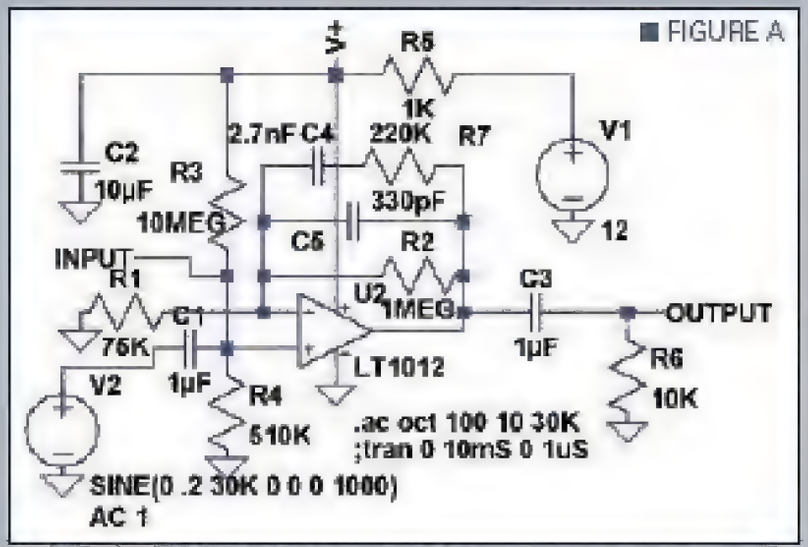
I hope this can assure you and your readers.

— Ron Wijngaarde

Dear Russell:

Re: Large Clock

■ FIGURE A



can't find a tube checker, just ohm the filaments; if the filament is good, it should do something. You did not mention a filament supply; these are probably 1.5 volt tubes (1R5, 1S4, etc.) but the filaments are probably connected in series; you will have to check that. There will be a high voltage supply producing 400 to 500 volts DC for the GM tube; if that is working and introducing a small signal to the amplifier produces an output but no clicking from the GM tube, then the GM tube is bad and you may as well start from scratch with a solid-state design and a new GM tube. This URL has some good information, including a schematic: www.circuitsarchive.org/index.phh/file:geiger-counter.png. NV

Revisited, March '10, page 31:

In looking at your code from March and researching the forum, try adding these parameters in your code before " start."

#Picaxe 28X1
SetFreq EM4 (or whatever speed you have selected)

Other SetFreq options: internal k31, k125, k250, k500, m1, m2, m4, m8, and internal em4, em8, em10, em16, em20.

I do not know if this will solve the problem or not, as I have never used an external crystal. Within a forum thread, this statement prompted the idea to use SetFreq to solve the matter: "Attaching a resonator won't automatically cause the 28X1 to use the resonator, you need to tell it to use that with the SETFREQ command. As you are using a 4 MHz resonator, you would use a 'SETFREQ EM4' command."

— Terry Meyer

Response: Thanks for your input, Terry, I think you have found the answer. I will put that in my memory bank.

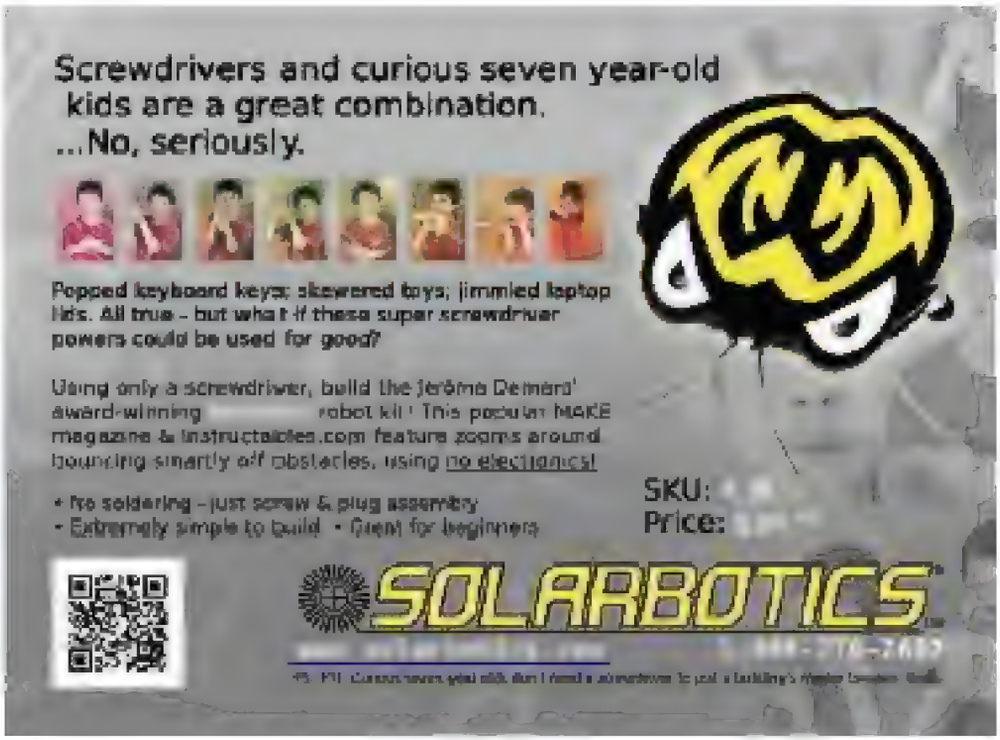
Dear Russell:

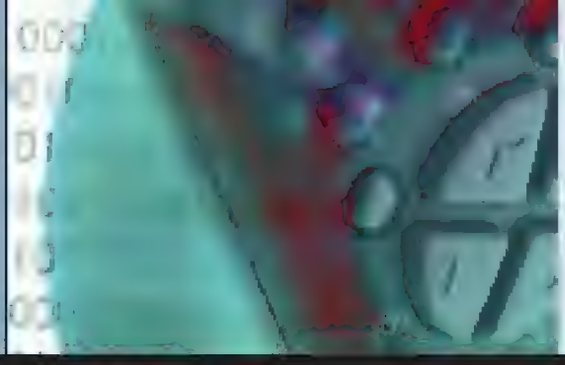
Re: Phono Preamp, April '10, page 22:

I enjoyed reading your April column as usual. I do have a comment on the phono preamp circuit. You say this has a flat response; surely it should be designed to implement the RIAA equalization curve?

— Robert Atkinson G8RPI

Response: You are right, but not being an audiophile, I didn't think of that. Also, I didn't realize that the wide line parameter had changed which caused the lines not to reproduce in printing. Consequently, I have re-done the schematic with compensation (Figure A). The response is not exactly RIAA, but close.





NEW PRODUCTS

- HARDWARE
- SOFTWARE
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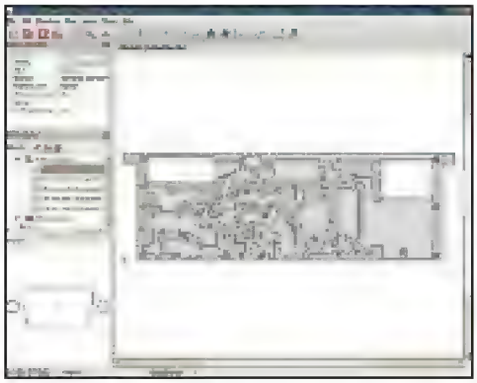
- TOOLS

MORE FLEXIBILITY, NEW FUNCTIONS, AND MAC OS X COMPATIBILITY

Front Panel Express has released a new version of their free design software: Front Panel Designer. This update can now run on Windows, Mac OS X, and Linux, has more design flexibility, and additional features. Additionally, manufacturing lead time has been reduced from seven to five days.

In the previous version of the software, making special shapes used to be an involved process. Now it is a simple file import. Before, users had to build custom shapes using a standard tool kit or send their designs in to have an engineer import them, but in version 4.0 a simple DXF file import does the trick. Front Panel Express has simplified and sped up the process of custom file imports by incorporating this feature in their CAD software. The import of DXF files makes the design of exterior and interior contours possible without restrictions, which means that the design of front panels is not limited to simple geometric shapes (as an example, see the screenshot). As with all Front Panel Designer features, the user can see an immediate price quote for their custom designs.



"Our customers let us know that they wanted to have more versatility and control over the design process. Now that we have given these to them, I am excited to see their new designs. The most unique ones will be featured in our monthly email newsletter," says Diane Haensel, CEO

Continued on Page 77

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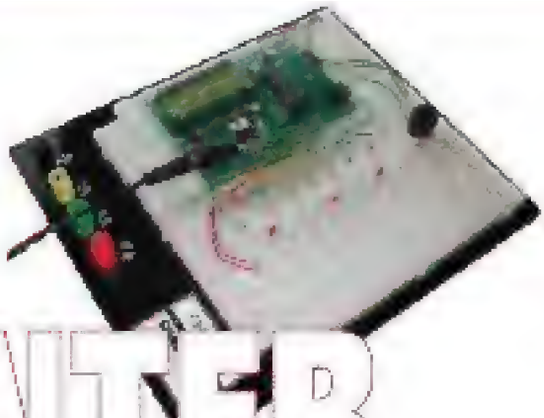
BY THOMAS KIBALO

IMPLEMENTING A DATA LOGGER WITH THE 16-BIT MICRO EXPERIMENTER

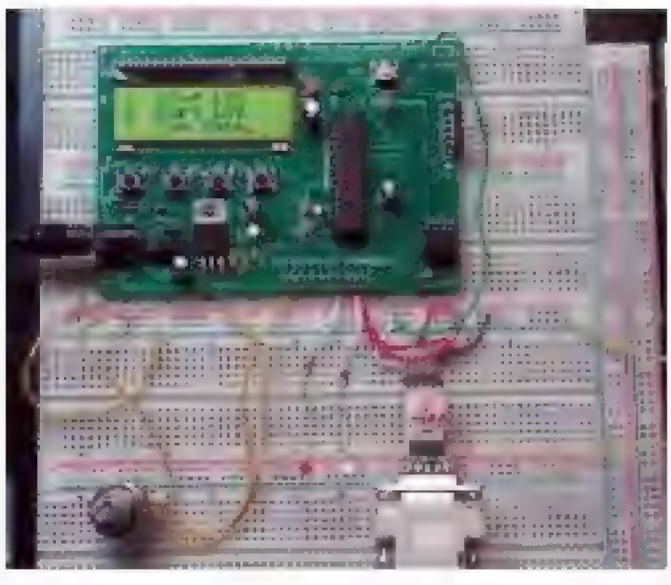


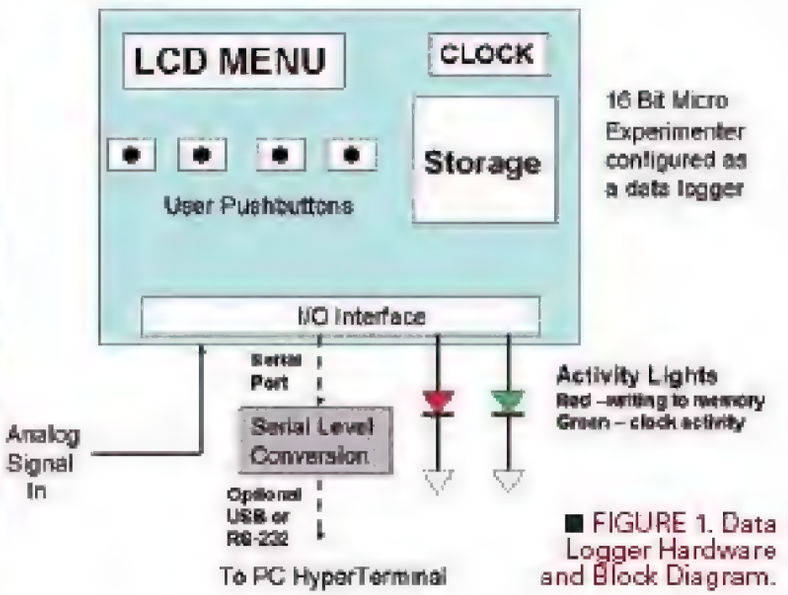
Previous *Nuts & Volts* articles have presented a series of demos with an overview of the 16-bit Micro Experimenter (Experimenter for short), its hardware features and C libraries for LCD displays, pushbuttons, and EEPROM and ADC operation. Now it's time to roll up our sleeves and put together a real working application. This article will use what we've learned so far to build a stand-alone data logging application using the Experimenter.

A data logger is very useful in experiments where long-term logging of time stamped data is needed. Imagine collecting and storing temperature readings throughout your house every 10 minutes over a four week period; understanding heating and/or cooling efficiencies; or measuring the voltage output from a solar collector every hour over six months to identify the best placement. A data logger can help make all this happen. In the course of this article, we are going to introduce two more libraries for the Experimenter: the Real Time Clock Calendar (RTCC) and the Serial Port. They will be used with what we have learned so far to build the data logger. As stated in previous articles, all software will be kept to a general level of understanding using straightforward functional calls. However, some basic familiarity with C language syntax will be required. For starters, let's look at the basic capabilities of the data logger that we will be building.

Data Logger Description

Figure 1 shows a notional data logging block diagram side by side with the actual Experimenter. We have the LCD configured for menus to allow the user to operate the data logger using pushbuttons. The RTCC (or clock) is used to set data and time of data capture, as well as rate of capture. The EPPROM (a full 32K x 8 byte non-volatile

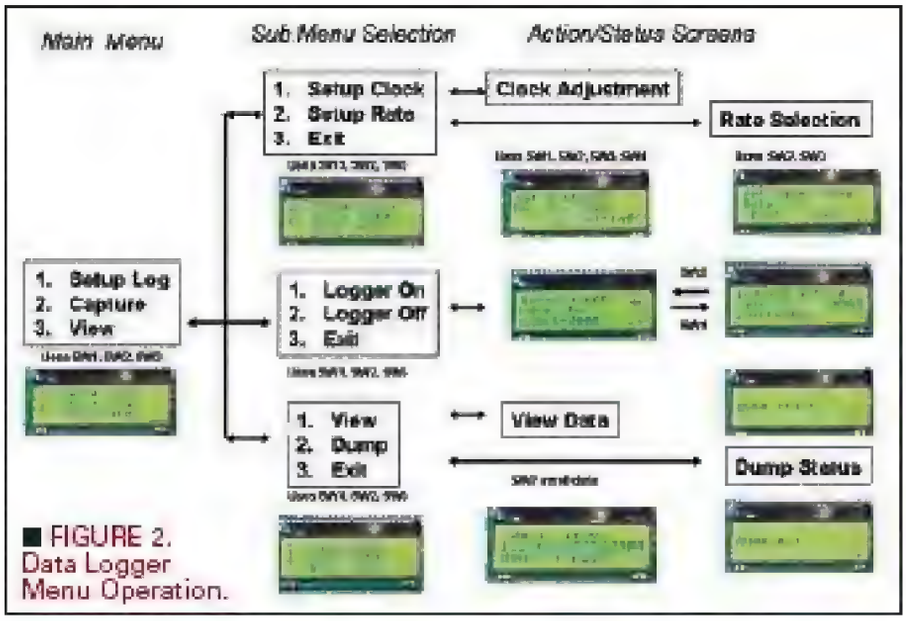




■ FIGURE 1. Data Logger Hardware and Block Diagram.

memory) functions as our storage. The I/O expansion bus is configured to accept an analog input signal and digitize it using the PIC24F ADC. This I/O expansion is also configured with a serial port to download data logger storage contents to a PC. We will use the HyperTerminal program on the PC to see the data logger in action and store the results in files. Once data is stored in a PC file system, we are able to do analysis and data plotting using standard PC office tools (like excel spreadsheet programs).

There are several LEDs that run from the I/O expansion bus for data logger indication activities: a red LED flashes when storage is updated; and a green LED flashes once a second to indicate the RTCC clock has been set and is active.



■ FIGURE 2. Data Logger Menu Operation.

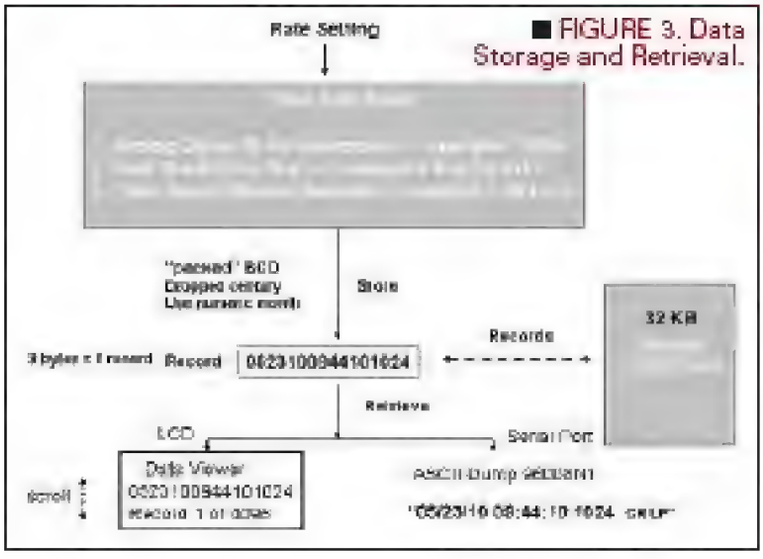
Data Logger Operation

A data logging application allows for interaction with the operator for control and to view status changes. In our case, we are going to implement a menu driven system. In fact, all the functionality we need is implemented through a series of menus and action/status screens. The main menu has options to set up a data log, initiate a capture, and then view data all using pushbuttons SW1 to SW4. From here, a user navigates through the menus to where action and status screens reside. No matter where a user ends up, in all cases he/she can recover and work their way back to the Main Menu. As with any new instrument or appliance, the best way to get familiar with it is to try it. A data logger project is available off the *Nuts & Volts* website (www.nutsvolts.com) or KibaCorp site (www.KibaCorp.com) complete with commented source code for this particular experiment. The menu driver for this experiment is contained in the MAIN.C function of the code.

What is the Data, and How is it Stored and Retrieved?

Okay, we understand the operation, but what is the data and how does the data logger store and retrieve it? The logger stores an analog value. It uses the ADC library (we learned earlier) and configures pin 1 of the I/O expansion bus to function as an analog input. Any analog input at this pin between 0 to +3.3 VDC will be converted to 10 bits and be represented as a decimal number from 0 to 1023. The logger will store this value along with the current data and time from the RTCC. Conversion can be set at different rates — the fastest being every 10 seconds and the slowest being once a year. All together, we end up with 16 ASCII characters for data, 16 ASCII characters for time, and four ASCII characters for a date — that's a total of 40 characters of data per event.

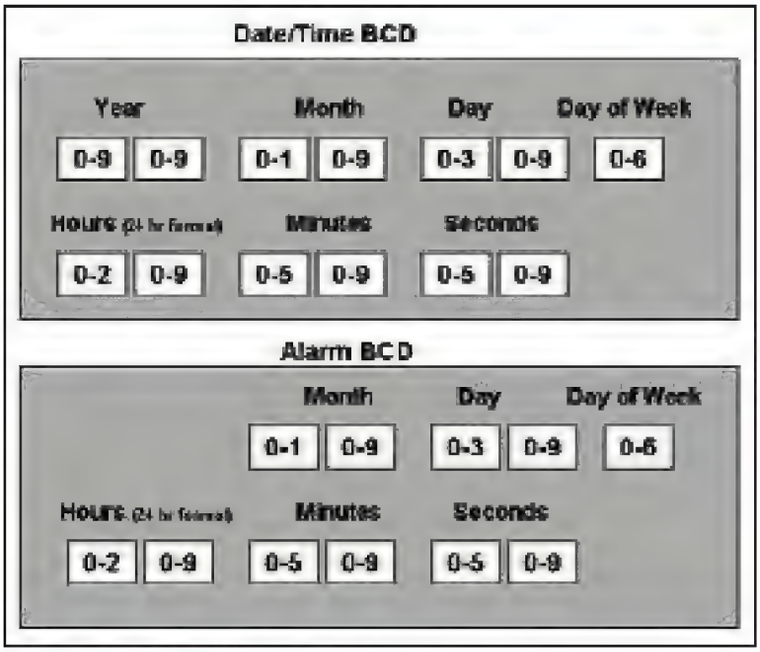
To store this efficiently, we compress the 40 ASCII character data events into a smaller eight byte record using a few tricks. These "tricks" amount to replacing the month with numbers, using only the last two numbers of the year and decade, stripping each ASCII character of its most significant common four-bit header, and then retaining the remaining least significant four bits (nibble) and "packing" these nibbles into bytes. We have 32 KB of storage with our on-board Experimenter EEPROM. With this smaller eight byte record, we can store a total of 4,095 events or records in our EEPROM (reserving an



■ FIGURE 3. Data Storage and Retrieval.

■ FIGURE 4. Logging Rates and Capacity.

Selected rate	Total Logging Time 4095 records
ev 10s	11 hours
ev 1 min	2.8 days
ev 10 min	4 weeks
ev hr	6 months
ev day	12 years
ev week	85 years
ev month	>100 years
ev year	>100 years

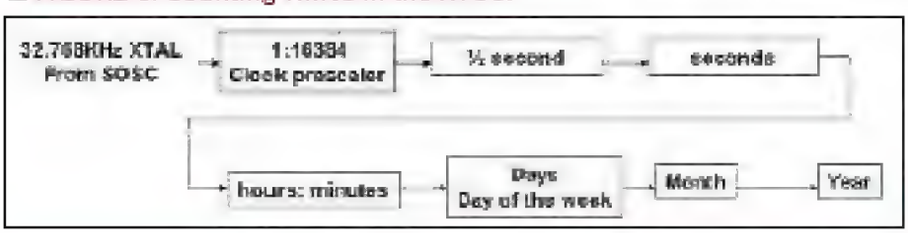


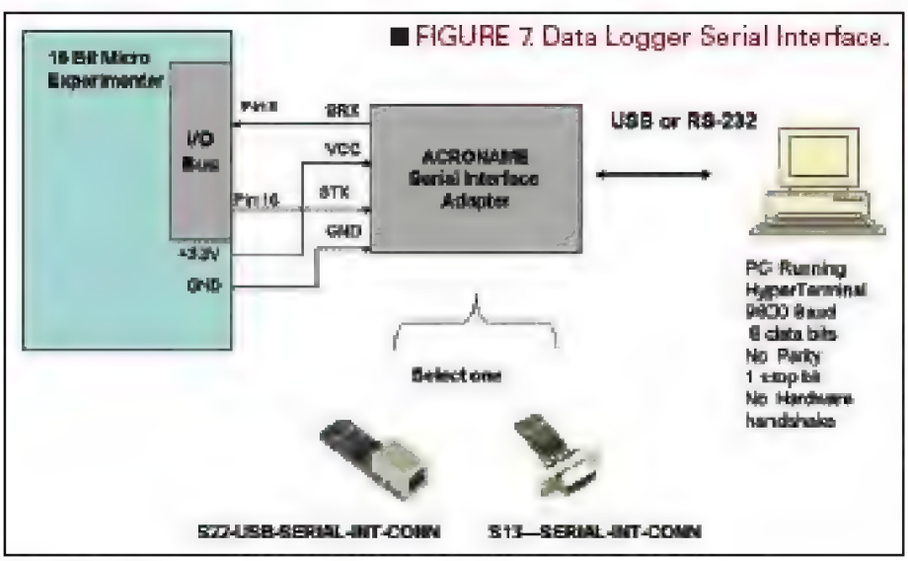
■ FIGURE 5. RTCC Value Registers.

additional spare area to store total record count). We work the EEPROM using the EEPROM library previously covered.

For retrieval, the record is "unpacked" and converted back to ASCII for viewing on an LCD display or downloading to a PC using the serial port. The EEPROM eight byte record is expanded to 16 character bytes (see **Figure** 3). If the record is transferred to the PC, it is additionally formatted with spaces and carriage return/line feeds for a nice visual presentation on the HyperTerminal display.

■ FIGURE 6. Counting Times in the RTCC.





■ FIGURE 7. Data Logger Serial Interface.

How Much Can be Stored?

Users get to select which logging rate they want and, as a result, incur a total logging time — if all total EEPROM is to be filled. When you examine all the supported RTCC rates and the total number of records that can be stored, the total logging time becomes quite impressive. We decided to cap the logging time to 100 years (after all, the RTCC is just a 100 year clock /calendar). For additional flexibility, the data logger (during logging operation) can be toggled on or off as needed to shorten logging times.

The Real Time Clock Calendar

The RTCC function is intended for applications where accurate time must be maintained for extended periods of time with minimum to no intervention from the CPU. The peripheral is optimized for low power usage in order to provide extended battery life while keeping track of time.

It features the 100 year clock/calendar with automatic leap year detection. The range of the clock is from 00:00:00 (midnight) on January 1, 2000 to 23:59:59 on December 31, 2099. The hours are available in a 24 hour (military time) format. The clock provides a granularity of one second.

The RTCC internal register interface with the PIC24F microcontroller is implemented using the Binary Coded Decimal (BCD) format. This simplifies the software when reading and writing to the module, as each of the digit values is contained within its own four-bit value.

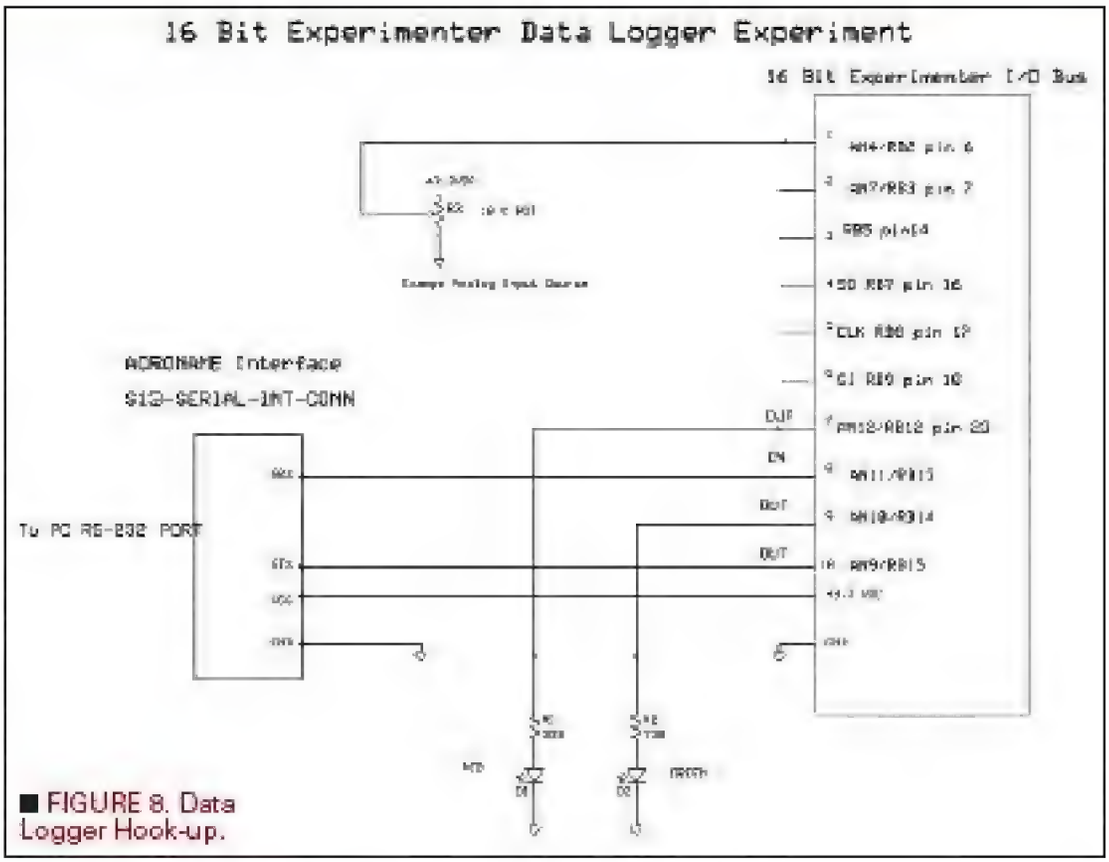
The RTCC module is clocked by an external real time clock crystal that oscillates at 32.768 kHz. The Experimenter comes with this crystal. The clock crystal connects to the PIC24F and works in conjunction with internal logic counters within the RTCC module to derive time (see **Figure** 6).

Using the RTCC Library

The Experimenter comes with an RTCC software library. The library contains a number of C function routines to initiate clock operations, set time/date, and read current time/date. We use all the clock functions for the data logger. In order to use the RTCC library, a #include RTCC.H must appear in your MAIN code, and the RTCC.C driver source code must be included as part of your project. We will also use an alarm setting function that works off of the RTCC to "alarm" or, in our case, to initiate a logging activity (more on this later).

- **RTCCInit**() — This function sets up the clock and initializes it to a default date and time.

- **RTCCSet()** — This function writes changed times and dates to the clock registers.
- **RTCCProcessEvents ()** — This function grabs the current time from the RTCC and translates it into strings. It must be called periodically to refresh the time and date strings _time_str and _date_str. Each string is 16 ASCII characters.



■ FIGURE 8. Data Logger Hook-up.

The above functions work directly with the RTCC without the advantage of using the LCD and pushbuttons — which would make working with the RTCC a lot easier. You could view the current clock setting on the display and selectively change fields and get instant feedback on the results. Because of this, I recommend that you use the following functions to set the clock and alarm instead. These functions make extensive use of the LCD and pushbuttons. To operate these, you must first call the library function RTCCInit (). The two functions we will discuss use the RTCC library, but reside outside of it in MAIN.C.

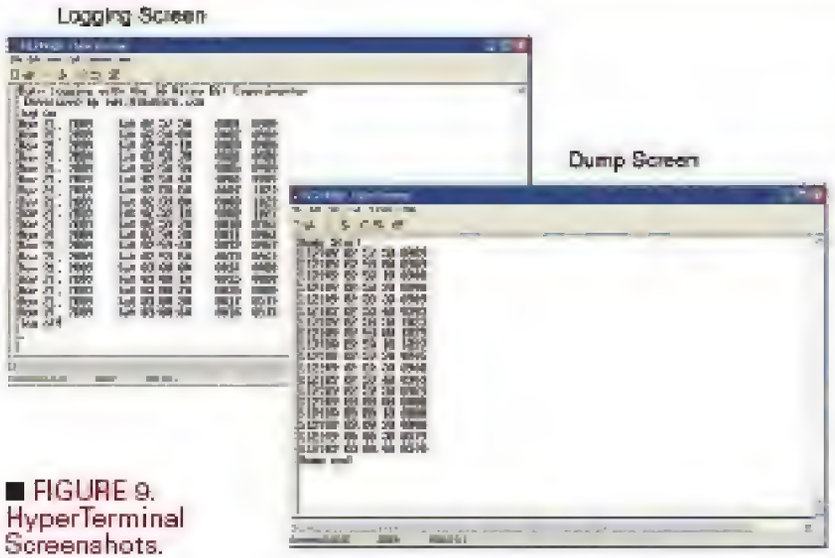
- **Set ALARM (alarm)** — This function initializes the alarm functions of the RTCC and sets the alarm (for the data logger, we referred to this as rate) based on the value passed as alarm. It is called during the rate setting menu. It sets as follows:
  - if (alarm = 0), then alarm every 10 seconds.
  - if (alarm = 1), then alarm every minute.
  - if (alarm = 2), then alarm every 10 minutes.
  - if (alarm = 3), then alarm every hour.
  - if (alarm = 4), then alarm every day.
  - if (alarm = 5), then alarm every week.
  - if (alarm = 6), then alarm every month.
  - if (alarm = 7), then alarm every year.

Once the alarm is set, this function will then enable the RTCC to interrupt the PIC24F once the alarm condition is met. The RTCC interrupt performs the function of collecting all the data for the record and then storing the record in EEPROM. It runs continuously until a total of 4,095 records are stored or until the operator elects to shut the alarm interrupts off (using menus) before the full 4,095 count is reached.

- **clock_Setup ()** — This routine displays the current RTCC time setting in ASCII and allows the operator to accept or make changes to the RTCC using the display and pushbuttons.
  - **Button SW1:** Toggles between the clock set mode and clock accept mode. Hitting the SW1 twice in accept mode exits the function with the RTCC set to the displayed time.
  - **Button SW2:** If in clock setting mode, it increments the current data field.
  - **Button SW3:** If in clock setting mode, it decrements the current data field.
  - **Button SW4:** Advance to the next allowable data field.

Implementing a Serial Interface

To connect the Experimenter data logger to a PC, a serial port is required. The port uses one of the two internal Universal Asynchronous Receiver Transmitters (UART) in the PIC24F and connects the transmit and receive pins to pin 9 and pin 8 of the I/O expansion bus. Why bother with this connection? Well, the data logger only does a single log session at a time. It stores this nonvolatile data from the logging session. However, if you initiate a new session, then this data will be written over — that is where the PC comes in. We don't need to lose our data, just simply transfer it to the PC with its larger file system and analytic tools, and store and study the data there. As a stand-alone, the data logger will allow you to examine the stored data under the menu operation. However examining all 4,095 records manually using pushbuttons to scroll through will be tedious!



■ FIGURE 9. HyperTerminal Screenshots.

You must do a #include "CONU2.H" in MAIN and also include the CONU2.C driver source code in your project to use the serial port. The serial port can support a PC serial port or USB with the proper physical interfaces. Acroname (**www.acroname.com**) provides ideal physical interfaces at a reasonable price.

Only four connections are required to work with the Experimenter. They are pin 9 and 8 of the I/O expansion bus, and +3.3V and GND, as well. If USB is required, some software INF files and USB drivers will need to be installed on your PC. (Acroname provides all the code and instructions with their product.) The CONU2 library functions used in the data logger are:

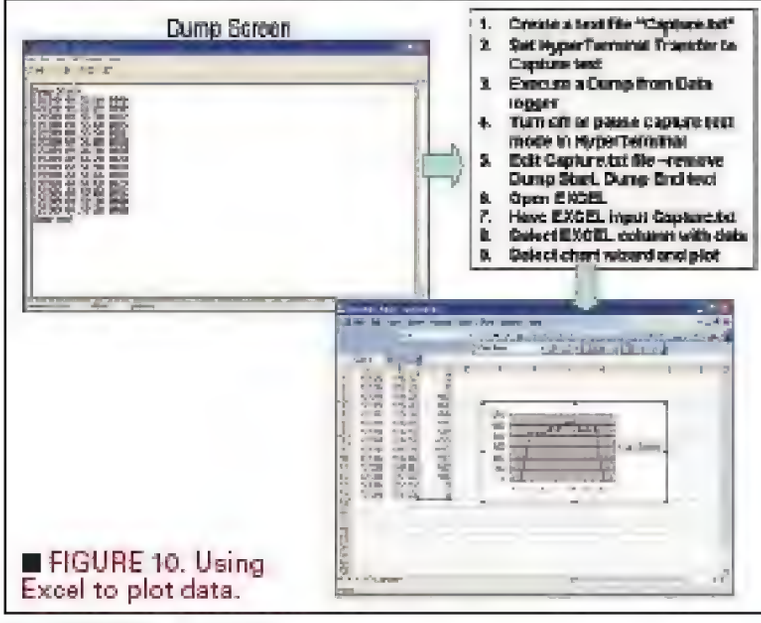
- **initU2( )** — Initializes the serial port using UART2 of the PIC24F for pins 8 and 9 of the Experimenter expansion bus for 9600 BAUD, eight-bit data, no parity, and one stop bit (or 96008N1 for short).
- **putU2(character)** — Writes a character out to the serial port.
- **putsU2(string)** — Writes an entire string out to the serial port.
- **Character getU2 ( )** — Waits for a new character to arrive to the serial port and then returns it.

Testing the Data Logger

Assemble the hardware using the connection diagram supplied in **Figure 8**. The Acroname interfaces and PC are not required at the start). I used a potentiometer as an analog source for this experiment, but you can hook up any type of sensor or input that does not exceed +3.3 VDC on its output. Download the data logger project from the *NV* website and use your free MPLAB IDE and PIC24F software compiler to compile the code; then use your PICkit2 to load the program into the Experimenter. Play with the menus, set up the logger, use the 10 second rate, and begin collecting. The data logger has defaults for the clock setting and 10 second rate to make things easier. As the system is collecting, dither the pot and watch the values on the display update every 10 seconds. This should coincide with the red LED flashes. Stop the logging and then use the data logger viewer (using the LCD and pushbuttons).

Now, connect the Experimenter to your PC using one of the designated interfaces (USB or serial). Bring up the HyperTerminal application. Configure HyperTerminal for 96008N1 and no hardware handshake. Start the data logger again and you should see a banner announcement on HyperTerminal indicating that the Experimenter is communicating. All logging activities will be displayed as automatic updates on the HyperTerminal Window. Once you finish logging, the data logger will "dump" all its stored record data — on your command — to HyperTerminal using the 16 byte record ASCII format. The data logger retains its records until the next logging session which allows you to execute a number of record "dumps" if necessary. Here's where the magic begins.

You can do analysis and plotting of this dumped record data using PC software (like Excel). To help you along, **Figure 10** shows a screenshot and the procedures to transfer a data record dump to a text file through HyperTerminal and import it to Excel for plotting.



■ FIGURE 10. Using Excel to plot data.

Ideas for Future Expansion

We now have completed our first real application for the Experimenter. It has some very practical capabilities, so put it to good use. I'm sure there are lots of ideas out there that can work with it. Stay tuned! More exciting applications are coming! **NV**

A complete kit to go with this series of articles can be purchased online from the *Nuts & Volts* Webstore at **www.nutsvolts.com** or call our order desk at **800-783-4624**.

SHAKE, RATTLE, AND ROLL
VIBRATION MONITOR

By Ron Newton

Build one for less than $10!

One of my students in Kenya, Africa needed a suggestion for a project that would be simple and inexpensive! I suggested a vibration monitor that could be used as an intrusion alarm. To make sure that it would work, I built my own. Since project cases always drive up the price of a project, I thought, "Why not put the project into a battery holder?"

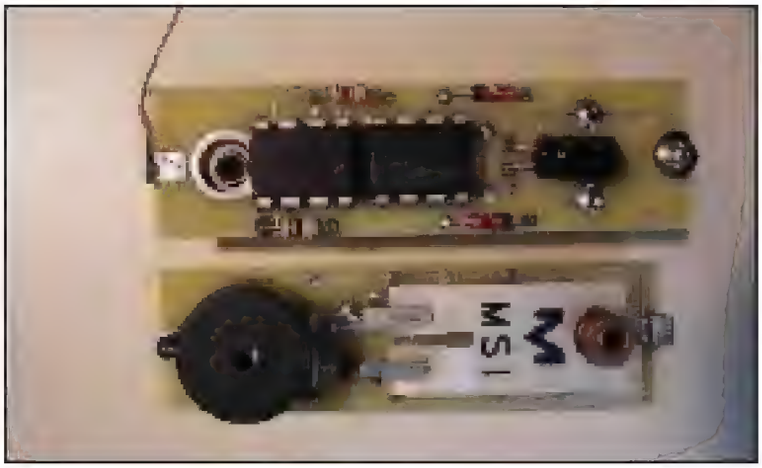
Eagle Plastics makes a three AA battery holder with a switch. I designed a circuit board the size of a AA battery that would hold all the components (total of nine), and used the center battery slot to power and hold the board.

Methodology

The detection transducer used here is a Measurement Specialist, Inc., LDT0-238K piezo film sensor that has a weight attached. This sensor can generate up to 70 volts when stressed and produces an AC current when vibrating. I found that very small vibrations produced small voltages that needed to be amplified, so I selected a Microchip MCP601. This is a 2.7 volt single supply amplifier and I used it in a non-inverting 101 amplification configuration.

$$\text{Amplification} = 1 + \left(\frac{R1}{R2}\right) = 1 + (100{,}000/1{,}000) = 101$$

By changing R2, you can increase or decrease the amplification. The board is designed to either use a fixed resistor or a potentiometer so that you can change its sensitivity. The voltage from the sensor is limited by using two signal diodes with opposite polarities in parallel, and feeding the sensor's output into an op-amp (see the **schematic**).



■ Top and bottom of board.

The output from the op-amp goes to a PIC12F508 which acts as a timer and tone generator for the speaker (magnetic transducer). The 10 µF capacitor passes only AC to the speaker and blocks any DC.

The PIC508 is inexpensive and is about as simple as microcontrollers can get. When it is put to sleep, it draws less than two micro-amps. The op-amp draws about 230 micro-amps, so in total the two AA batteries should last for over a year. I put in a one minute delay so that the unit can be set down and arm itself. To save power, I use the 508's sleep function.

When the micro is sleeping, there are a couple of things that can wake it up. I used a watch dog timer (WDT) and a pin change on one of the input pins (GP0). I set the WDT to wake up every 2.3 seconds; when this happens, it increments a counter. When the counter reaches 26 (60 seconds), it arms the alarm. If the sensor detects any movement, it changes pin 7/GP0's voltage and this causes it to alarm.

How does the micro know what woke it up or if it just turned on? With the status register. By checking the bits in the status register, the micro will either jump to the program area to increase the count or jump to sound the alarm.

The magnetic transducer has a resonate frequency of 2,400 kHz ± 200 Hz. I wrote a program that will warble around 2,400 kHz for maximum sound. There are two other alarms written in the software code. If you want to use them, you will need to change the software GOTO to the different locations. One is a French ambulance alarm; the other is a single tone. This will require you to have a programmer for the chip and understand writing code. (A pre-programmed chip is available from the author.) If you're feeling ambitious, you can even write little tunes that it can play.

The magnetic transducer is activated by turning it on and off using a square wave generator. The resonate frequency (being 2,400) needs a square wave of 417 micro-seconds.

$$\frac{1}{2{,}400} = .0004167$$

This is controlled by a counting loop in the software in **Listing 1**.

Construction

If you'd like to make your own boards, the files are available on the *Nuts & Volts* website (**www.nutsvolts.com**) along with the software code, tips, and suppliers of parts. Go to **www.expresspcb.com** and download their free software for making your own boards and schematics. This software will open the files on the website.

Pull the two wires coming out of the battery box back into the battery box. Slide a piece of heat shrink tubing over the black wire. Cut them to a length so that you can still solder them, and then parallel solder them together. Slide the heat shrink tubing over the solder joint and push them inside the box next to the switch.

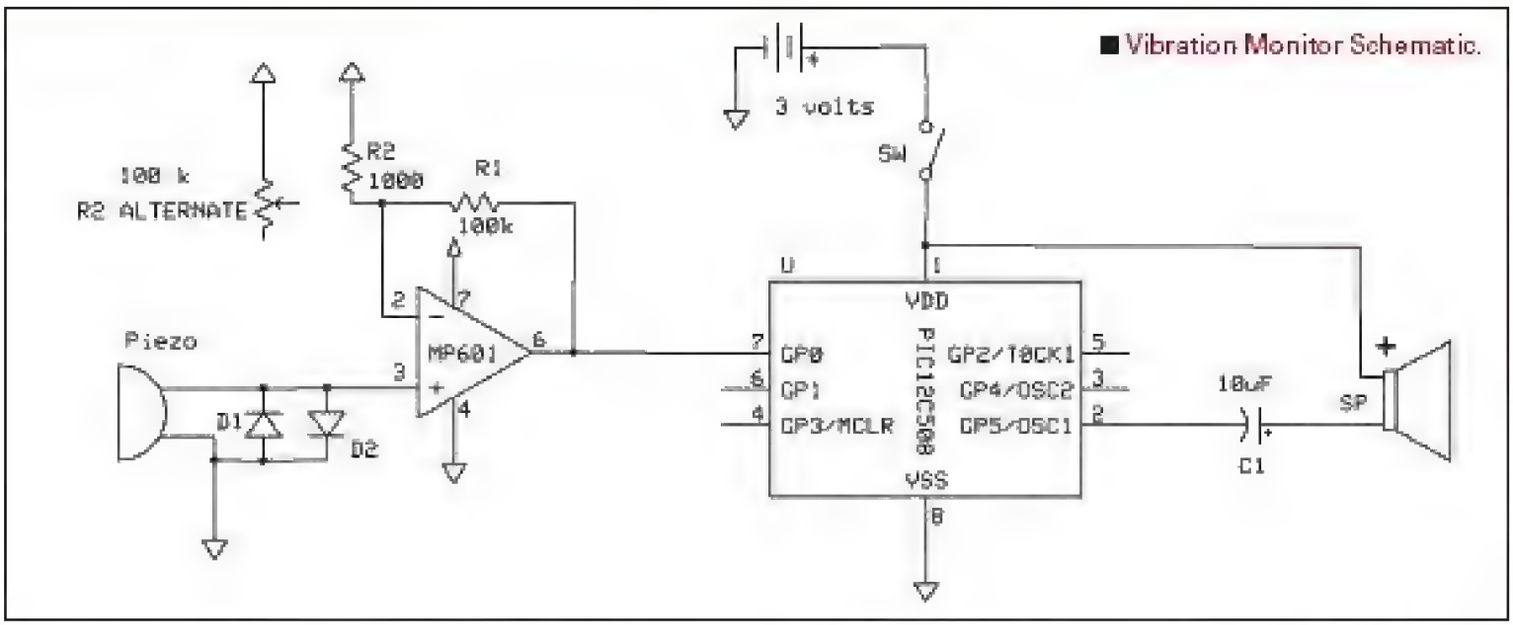
Use the board as a template and place it into the center battery compartment of the battery box. The + mark should be next to the spring of the battery compartment. At first, you might think that's wrong but it's not. Move the board toward the spring about 1/16". Using a small drill, make a hole in the center of the speaker area into the box. Turn it over and using the small hole as a guide, drill a 1/4" hole in the battery box. Be careful not to drill through the spring. This hole is for the output of the speaker. Depending on how you are going to use the alarm, you can glue a magnet on the back or pop-rivet a lanyard so that you can hang it on a doorknob.

Board Assembly

Tap the hole at the end of the board next to the speaker with a 2-56 tap. This will be for a screw which will make contact with the

■ Listing 1.

```
TONE
MOVLW   .068            ;LOADING A NUMBER TO BE DECREMENTED FOR FIRST
                        ;HALF OF SQUARE WAVE (THIS SETS THE TONE)
MOVWF   LOOP1           ;MOVE IT INTO LOOP 1
BCF     SPEAKER         ;TURN ON SPEAKER (GROUND THE SPEAKER)
DECFSZ  LOOP1,1         ;COUNT DOWN LOOP 1 UNTIL ZERO AND SKIP NEXT
                        ;COMMAND
GOTO    $-1             ;JUMP BACK ONE UNTIL ZERO
MOVLW   .068            ;RELOAD  NUMBER TO BE DECREMENTED FOR OTHER
                        ;HALF OF SQUARE WAVE
MOVWF   LOOP1           ;MOVE IT INTO LOOP 1
BSF     SPEAKER         ;TURN OFF SPEAKER (BOTH TERMINALS OF SPEAKER
                        ;POSITIVE)
DECFSZ  LOOP1,1         ;COUNT DOWN LOOP 1 UNTIL ZERO AND THEN SKIP
                        ;NEXT COMMAND
GOTO    $-1             ;JUMP BACK ONE UNTIL ZERO
GOTO    TONE            ;KEEP DOING UNTIL POWER IS SHUT OFF
```



■ Vibration Monitor Schematic.

battery compartment's spring.

I had trouble making a contact for the other end of the board. At first, I tried to make a contact similar to the positive end of a battery but the contact was poor and intermittent. I ended up taking a 3/4" length of solder braid and soldering it to the bottom square pad on the board with its tail coming out to the right side. When putting the board into the box, I threaded it through the contact slot and into the first turn of the spring for the battery (on the left). This solved the problem.

If you want to have adjustable sensitivity, solder the R2 alternate potentiometer to the board and leave the fixed R2 vacant. Mount the two ICs, diodes, and R1 and R2 (if you want fixed amplification) to the top of the board. The square pads are pin 1. Watch the polarity of C1 and bend the leads so C1 will lie flat on the board and then solder. Screw a 3/8" 2-56 screw from the top side into the tapped hole.

Turn the board over. Bend the piezo transducer leads at right angles where the contacts enlarge (no polarity) and solder on the bottom side of the board. Make sure that the sensor is centered with the board and that the piezo film is about 1/16" above the bottom (of the board) so that it can vibrate. Solder the speaker, noting its polarity on the bottom side. The screw should be protruding next to the speaker.

Testing

Place the board into the center position of the battery compartment and add two AA batteries to each side (note their polarities). Turn on the switch and set the unit on a quiet counter. After a minute, strike the counter with your hand. This should sound the alarm. Reset the unit by turning off the switch.

Once the unit is tested, glue the speaker to the bottom of the box so the board will not move. Replace the battery cover and secure it with the small screw to the battery case.

PARTS LIST

ITEM	QTY	DESCRIPTION	SUPPLIER
Battery Holder	1 ea	12BH331/CS-GR	Eagle-plastics.com
C1	1 ea	10 µF 16 volt radial	
D1-D2	2 ea	1N914	
IC 1	1 ea	PIC12F508	Microchip.com
IC 2	1 ea	MCP601	Microchip.com
Piezo Vibration Detector	1 ea	LDT0-0128K	Meas-Spec.com
R1	1 ea	100K 1/8 watt	
R2	1 ea	1,000 1/8 watt	
R2 Alternate	1 ea	100K potentiometer	
Screw	1 ea	2-56 3/8"	
Speaker	1 ea	WT-1205	Soberton.com
Board	1 ea	$10.00*	
Pre-programmed chip	1 ea	$5.00*	
Shipping and handling		$5.00*	

*Ron Newton
2230 Damon Rd.
Carson City, NV 89701
sjnewt@att.net
775 885-8842

Uses

This device can be used as an intrusion alarm or as an earthquake detector by changing its amplification. How about as a computer alarm if you walk away from your desk? It also could be used for analyzing motor vibration frequencies, or perhaps as an anti-feedback controller for microphones since there is plenty of room for more code. For remote monitoring, a relay can be substituted in place of C1 and the speaker. Run wires to a light or bell.

Here's to finding your own good vibrations. NV

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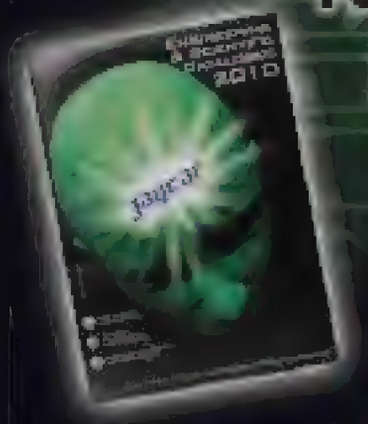

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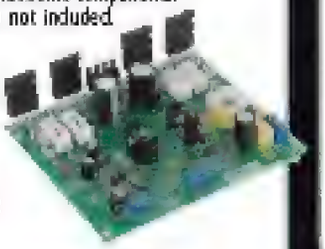
- Frequency response: 4Hz to 50kHz, 1m
- Harmonic distortion: <0.008% @ 20Hz-20kHz



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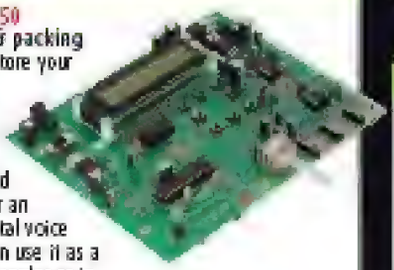

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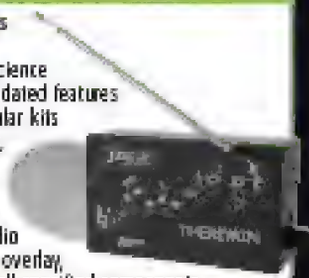

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- PCB: 47 x 44mm

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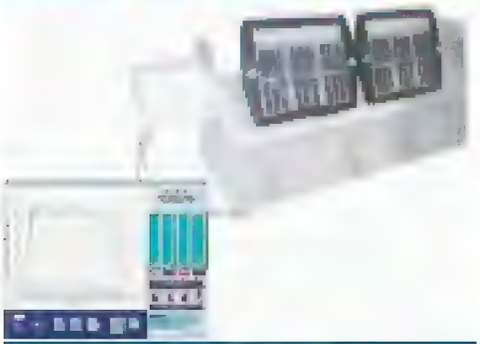

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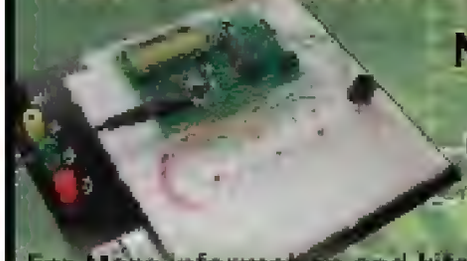

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www.dimensionengineering.com/Sabertooth2x50HV.htm

FUNDAMENTALS FOR THE BEGINNER

WHAT A RESISTOR DOES

Basically, a resistor restricts electron flow. It acts just like a funnel does for water. A resistor allows a certain amount of electrons to flow, depending on the voltage (pressure). By doing this experiment, you will see that the higher the value in ohms of a resistor, the fewer the amount of electrons that will flow; thus, the dimmer the LED will be.

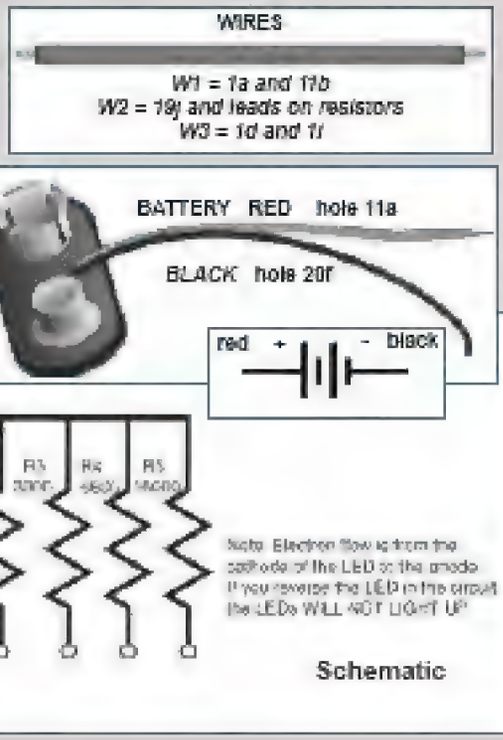
1. Build the Circuit.

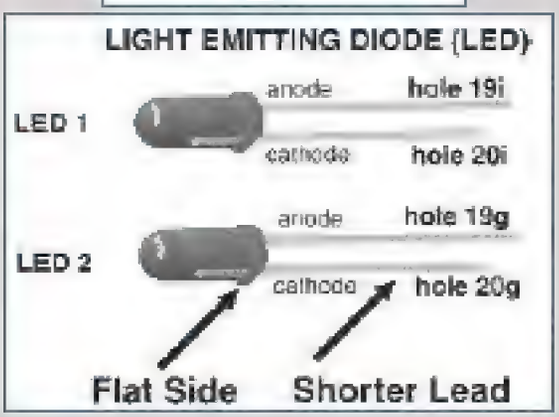
Using the schematic along with the pictorial diagram, place the components on a solderless breadboard as shown. Verify that your wiring is correct.

2. Do the Experiment.

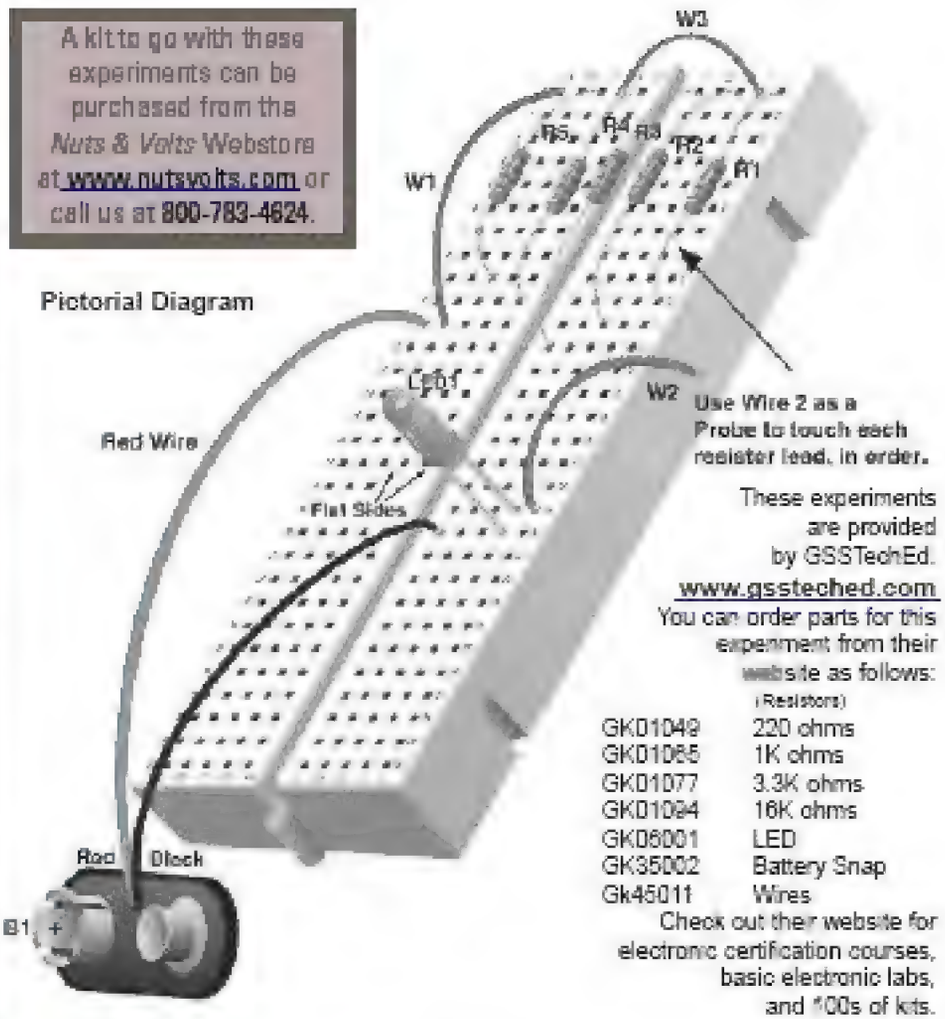
Theory: In this simple experiment, we will light up an LED (light-emitting diode) with a battery. The electrons will flow out of the battery through the LED, through the resistor, and back to the battery. Remember, a resistor gives opposition to the flow of electrons. So, the more electrons that flow, the brighter the LED will light up. The fewer the electrons flowing, the dimmer the LED will be.

Procedure: Connect a nine-volt battery to the battery snap and begin touching the probe (wire 2) to each resistor lead, one at a time. Observe the brightness of the LED. You should see it get dimmer as you go from R1 to R5.





A kit to go with these experiments can be purchased from the *Nuts & Volts* Webstore at www.nutsvolts.com or call us at 800-783-4624.



These experiments are provided by GSSTechEd.
www.gssteched.com
You can order parts for this experiment from their website as follows:

	(Resistors)
GK01049	220 ohms
GK01065	1K ohms
GK01077	3.3K ohms
GK01094	16K ohms
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The Projects of PROTOTYPE THIS

PyroPack

All photos and figures by Joe Grand unless otherwise noted. The PyroPack in action photo by Bill Florido.

Prototype This — an engineering entertainment program on Discovery Channel — offered a view into the real-life process of designing and building unique, sometimes crazy prototypes. The 13 episode series was filmed over the course of 18 months and aired starting back in October '08. Re-runs are currently being shown around the world, so be sure to check out the program!

I was the team's electrical engineer and hardware hacker, and shared the screen with Zoz Brooks, a roboticist and software designer specializing in human-machine interaction; Mike North, a material scientist and mechanical engineer; and Terry Sandin, a special effects veteran. We were challenged to build things that had never been done before, looked cool on TV, and could be completed within the extremely tight financial and time constraints of television production, all the while being followed around by a camera. It was a great experience to say the least!

This series of articles covers the electronic aspects of some of my favorite projects from the show. My hope is that you will be inspired, learn something new, or use my work as a building block for your own open source project.

Introducing the PyroPack

Featured in the Robotic Firefighter Assistant episode, the PyroPack is a high-tech firefighter pack containing the standard array of firefighting necessities (a self-contained breathing apparatus and personal safety system) coupled with some advanced features (thermal imaging camera, heads-up display, digital pressure gauge, and firefighter identification system). The goal of the project was to improve on the common firefighter equipment used and worn by a firefighter to help increase their efficiency and reduce their risk while on the job. Firefighters are very particular about the equipment they rely on, so designing something they would actually want to use was no simple task. We only had two weeks from initial concept to final test, not to mention the added stress of having my extremely pregnant wife due to give birth at any moment!

The PyroPack has two major subsystems:

1) Headset
2) Backpack

The headset is a non-intrusive, head-mounted, physically adjustable unit containing an infrared thermal imaging camera, a heads-up microdisplay, and a connection to the custom electronics located in the backpack. The backpack contains a large tank of compressed breathing air, a digital pressure transmitter, a small dry-chem fire extinguisher, Makita 18V LXT Lithium-ion battery, and circuitry. A supplemental arm-shield is mounted to the wearer's left arm which houses the dry-chem pull-tab trigger mechanism and output port, and serves as a simple mounting point for the RFID reader used with the PyroPack's Firefighter Identification System.

The backpack's housing was designed by industrial designer Scott Summit of SUMMIT ID (www.summitid.com) and fabricated using a number of rapid prototyping 3D printing processes, including SLS (Selective Laser Sintering) and DMLS (Direct Metal Laser Sintering) by Forecast3D (www.forecast3d.com). The curvature of the backpack is intended to prevent the pack from being snagged on wires and debris during firefighting operations in constrained environments.

The heart of the PyroPack is the electronics which process data from a variety of sensors, receive a

composite video image from the headset's thermal imaging camera, overlay the desired text and graphic information onto the image, and send the newly-created video signal to the headset's microdisplay. I incorporated a simple MEMS-based accelerometer to detect movement of the wearer or lack thereof, a digital pressure transmitter to convey the pressure (and remaining percentage) of the tank of compressed breathing air, and an RFID (Radio Frequency Identification) module used to read the unique identifiers of low-cost RFID tags and to serve as a robust Firefighter Identification System.

Joe modeling the PyroPack: headset (left) and backback (right). *(Photos by Boj Florido.)*

Infrared Thermal Imaging Camera and Heads-Up Microdisplay

The headset contains an L-3 Communications Thermal-Eye 3600AS OEM infrared thermal imaging camera core (**www.thermal-eye.com/products/3600as.htm**) and eMagin SVGA OLED-XL Microdisplay with WFO5 Prism Optic and Module (**www.emagin.com/products/OLEDMD/OLED-XL.php**). The headset attaches to the side of a standard firefighter SCBA (Self-Contained Breathing Apparatus) mask and is adjustable by sliding the entire unit in front of the wearer's field-of-view (over his left eye). It can also slide completely out of the way, allowing for an unobstructed view of the area when desired. Because the thermal imaging camera is forward facing and in direct line-of-sight with the wearer's eye, the image provided by the camera is a thermal view of the exact scene the wearer would normally see with his eye. Retail price of both the thermal imaging camera and microdisplay are in the tens of thousands of dollars. As our budget could not support such expenses, L-3 and eMagin graciously provided the units to us for use on the episode at no cost. Video overlay is achieved with a Decade Engineering BOB-4-H Video On-Screen Display module (**www.decadenet.com/bob4/bob4.html**). Controlling the text and graphics to overlay on the composite video image sent by the thermal imaging camera was achieved simply by sending a small number of commands via serial interface to the BOB-4-H.

The microdisplay's primary image is that of the infrared thermal imaging camera. The temperature scale on the right side of the screen is a feature of the camera and denotes the temperature in degrees Fahrenheit of whatever object is positioned in the center of the thermal imaging camera's field-of-view. The lower portion of the display — defined by a white box and black text overlaid onto the thermal imaging camera image — is where the PyroPack's sensor information is displayed:

1. Information pertaining to the Firefighter Identification System (not shown in this image).
2. Motion detection status (triggers an alert when no motion of the wearer is detected for a pre-set amount of time).
3. Remaining percentage of compressed breathing air available in the wearer's on-board tank (based on a full tank pressure of 3,000 PSI).

Motion Detection

A Memsic 2125-GL two-axis accelerometer (**www.memsic.com** or **www.parallax.com**; search for product code "28017") serves as a motion detection mechanism. When no motion of the wearer is detected for 30 seconds, a "MAYDAY" text is overlaid on the heads-up microdisplay image to alert and/or remind the wearer that he needs to keep moving. Support exists in the electronics to enable a transistor which will switch on or off a relay. The relay can be connected to many types of alerting devices (such as wireless transmitters) to wirelessly broadcast to all personnel within range that the wearer is in distress and not moving, or to visible or audible indicators (such as flashing lights or high-decibel sirens).

Status of Remaining Breathing Air

Currently existing pressure gauges are bulky units that are mounted on the outside of the firefighter (typically to the frame of their pack), so the gauges are commonly in the way, bouncing around during active movement, and

can get caught or snagged on wires or debris.

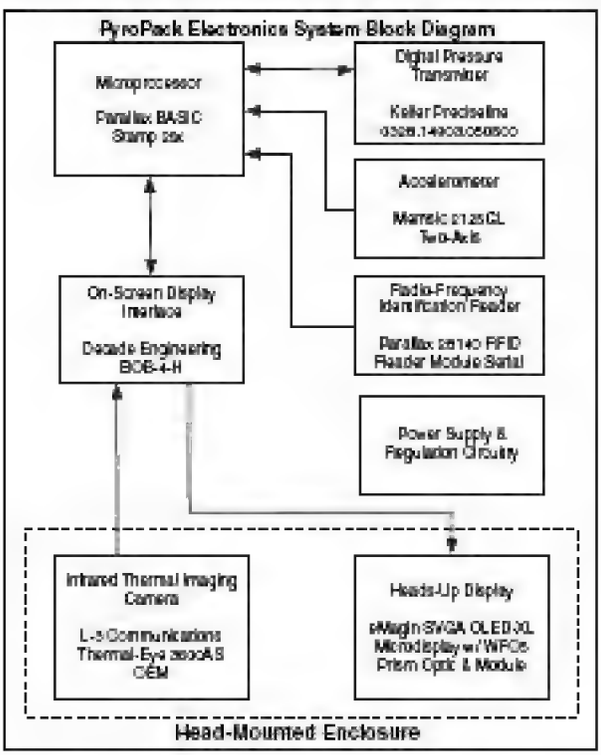
I used a Keller Preciseline 0328.14903.050500 digital pressure transmitter (www.kelleramerica.com/above-ground-pressure-transmitters/) to provide a reading of the current pressure of the backpack wearer's on-board tank (containing compressed breathing air). The digital pressure transmitter connects to the main circuitry via an industry-standard RS-485 bus (http://en.wikipedia.org/wiki/EIA-485/). It transmits a data stream (corresponding to the current pressure of the tank) to the BASIC Stamp 2sx. The BS2sx converts the data into a percentage of remaining breathing air based on a full tank pressure of 3,000 PSI (pounds per square inch) and overlays the result on the headset's microdisplay.

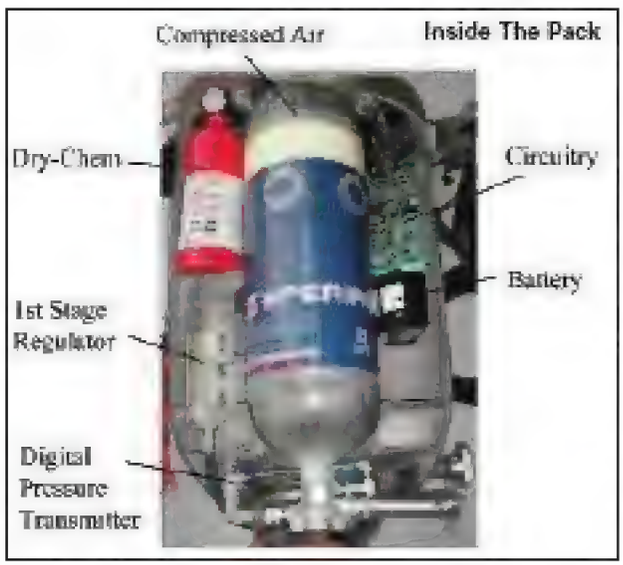
Firefighter Identification System

In many situations — particularly firefighting endeavors such as search and rescue — it is extremely difficult or impossible for a firefighter to identify other firefighters within a low- to no-visibility environment, such as a dark or smoke-filled room. The intent of the PyroPack's Firefighter Identification System is to allow a simple, quick, and effective method for a firefighter to identify other firefighters with minimal interruption to their primary job. Typically, identification consists of one firefighter approaching another firefighter and yelling "Who are you?" which is not always effective. While the headset's thermal imaging camera allows the firefighter to visually locate a human, it does not provide them with any identifying markers about who the human is or what his or her role is. The Firefighter Identification System supplements the thermal imaging camera by properly identifying the target after it has been located.

The PyroPack uses a handful of low-cost RFID tags embedded into the Firefighter's regulation clothing at pre-determined positions (for example, left and right shoulders, back of neck, left and right chest, left and right hamstrings, left and right quadriceps, etc.). Each RFID tag contains a unique identifier that can be read by a Parallax RFID reader module (search for product code "28140") which is mounted on the wearer's arm and connected via four-wire cable to the PyroPack's main circuitry. When the RFID reader module comes within approximately three or four inches of an RFID tag, the unique identifier of the RFID tag will be received by the reader and processed accordingly. The BS2sx is pre-loaded with a look-up table of known RFID tag unique identifiers and corresponding identification information. For example — for our prototype — eight unique IDs are associated with a single firefighter (allowing greater dispersion of RFID tags on the firefighter's clothing which, in turn, allows for a greater chance of the RFID reader module coming in close contact with a tag) and four firefighters are supported. Of course, in a real-world situation, the look-up table would need to be updated on-the-fly and/or in the field in order for the system to always have the most accurate identifying information.

In our prototype, when a valid RFID tag is read the last name of the firefighter is displayed on the microdisplay. The identifying information can be changed to any desired textual or graphical information, including (but not limited to) full name, rank, engine number, or role. Furthermore, the Firefighter Identification System could be easily expanded to not only identify firefighters, but also provide quick detection of entrance or egress points (for example,





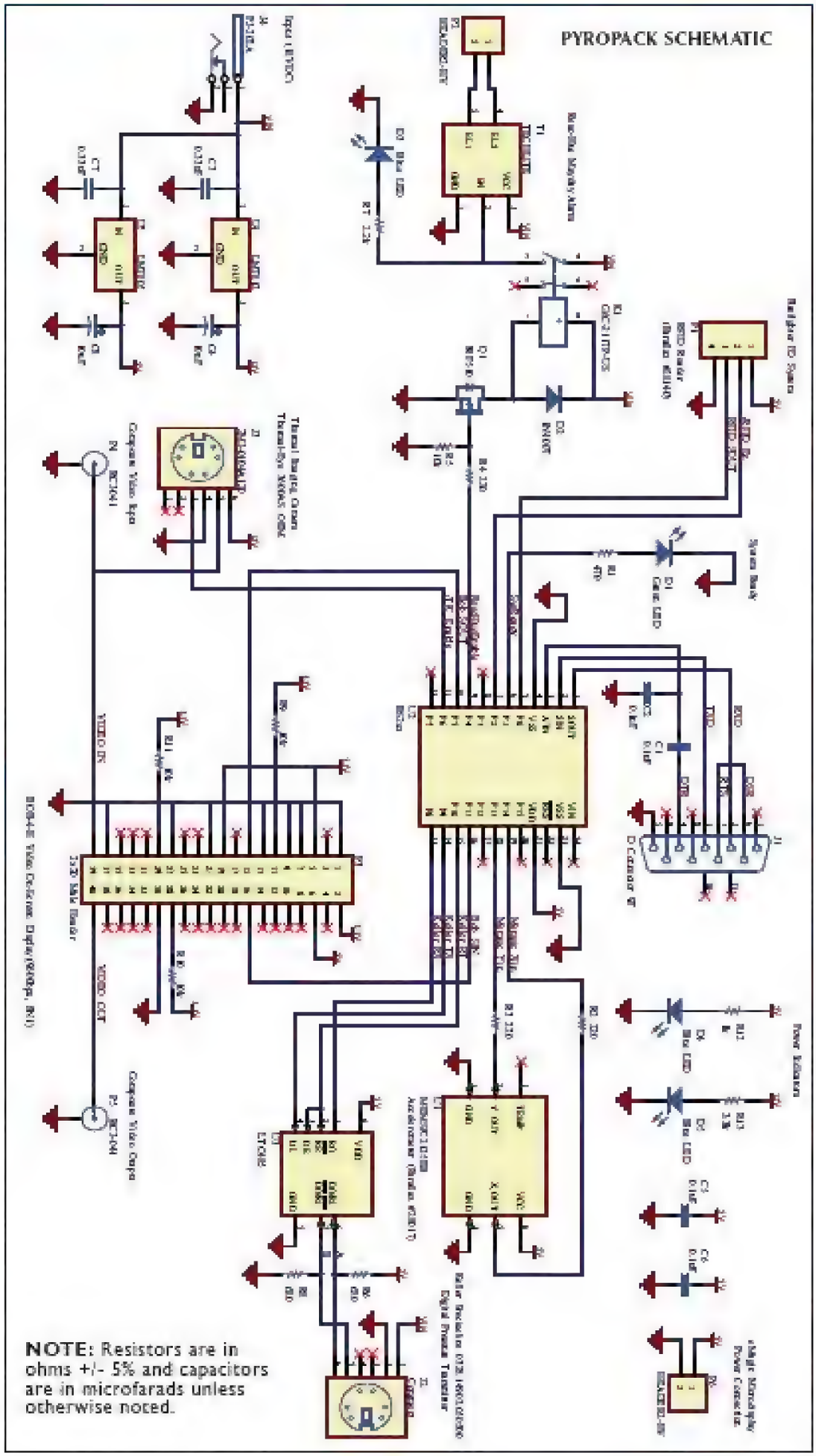
by sticking an RFID tag on the edge of a door frame) or triage of victims within the target building (by placing RFID tags on victims to classify them as minor injury, serious injury, or mortally wounded).

RFID is a mature technology robust enough to be used in the most offensive environments, including high-temperature, smoke-filled rooms. The system works via inductive or capacitive coupling and is impervious to room size, fire, smoke, or other objects that could affect other communication systems such as RF/wireless or optical. If the RFID tags embedded into the firefighter's clothing get worn out, burned, or damaged in any other way, they can simply be replaced and the Firefighter Identification System look-up tables updated to reflect the change in unique identifier of that particular firefighter.

Solving a Real Need

This build was particularly enjoyable because we designed something that could actually help people and potentially save lives. In the finale of the episode, we gave firefighters from Modesto, CA a demonstration of the technology and let them wear the unit during training scenarios. They were impressed with the functionality and agreed that there is a need for features of our system to be included in real-world firefighter equipment. Hopefully, one day we'll see that happen! **NV**

Joe Grand is an electrical engineer, hardware hacker, and president of Grand Idea Studio, Inc. (www.grandideastudio.com), where he specializes in the invention, design, and licensing of consumer products and modules for electronics hobbyists. He can be reached at joe@grandideastudio.com.



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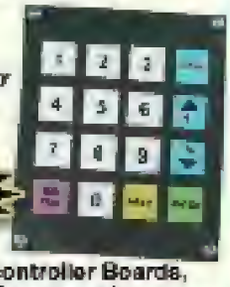

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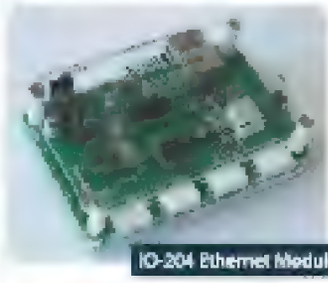

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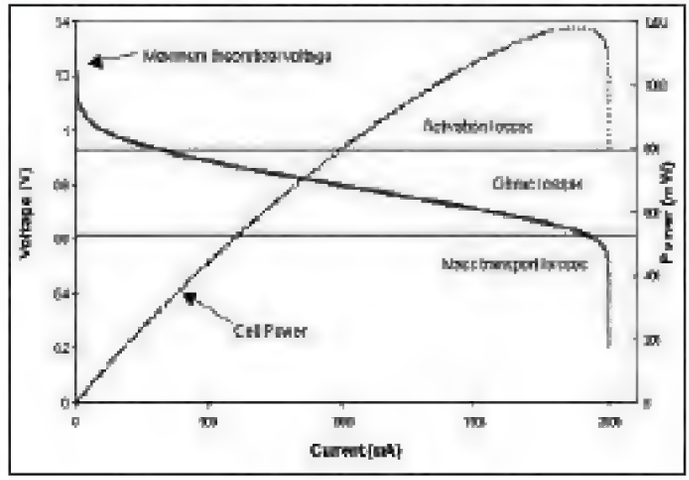
Experiments with Alternative Energy

Part 11 - Fuel Cell Polarization States and Efficiencies

By John Gavlik, WA6ZOK

Last time, I introduced you to the reversible PEM fuel cell and described its fundamental Electrolysis and Fuel Cell modes along with the minimum water decomposition voltage needed to electrolyze water into hydrogen and oxygen. This time, I'll delve deeper into the characteristics of the fuel cell by describing its three primary operational conditions called polarization states, along with two ways that fuel cell efficiencies are defined and measured. From this description, you'll see that a PEM fuel cell operates much like a rechargeable battery except for the fact that a battery stores its fuel internally while a fuel cell stores it externally. Aside from that, the similarities are quite remarkable.

Figure 1. Sample PEM Fuel Cell Polarization States.



Polarization Characteristics

Let's start with a fuel cell's polarization characteristics. In an ideal world, the fuel cell's optimum theoretical voltage of 1.23V would be realized at all operating currents; this is the water decomposition voltage you learned about in Part 10. However — like batteries — the output voltage is at maximum only at open circuit conditions, and the voltage drops with increasing load along with the resultant current draw. This is known as polarization and is represented by an example polarization curve shown in **Figure 1**.

The polarization curve characterizes the fuel cell's voltage as a function of current (and vica versa); as the load changes, so does the current — up to the point of what the "fuel" can supply (in this case, hydrogen and oxygen). Any more current demand causes the voltage to drop dramatically to zero. In effect, the polarization curve illustrates the electrochemical efficiency of the fuel cell at any operating current, since one efficiency is the ratio of the actual cell voltage divided by the theoretical maximum of 1.23V. This is called the Energy Efficiency that we'll examine later. There is also something called the Faraday Efficiency which we'll cover, as well. Plus, we'll do experiments to measure each one.

As I mentioned in the beginning, batteries have polarization curves very much like fuel cells as both batteries and fuel cells exhibit excellent partial load performance since voltage increases as the load decreases and vica versa. And, like batteries, fuel cell polarization is caused by chemical and physical factors associated with internal components, mainly the MEA (Membrane Electrode Assembly) that you learned about last month.

Polarization States

There are three polarization states:

- Activation
- Ohmic
- Mass Transport

Activation

Activation polarization is related to the energy barrier that must be overcome to initiate a chemical reaction between reactants. At low current draw, the electron transfer rate is slow and a portion of the electrode

voltage is lost in order to compensate for the lack of electro-catalytic activity. As you can see in **Figure 1**, this is the steep part of the voltage-current curve on the left. Due to the chemical energy barrier, the internal resistance at the very beginning is very high which accounts for the low current. Once this barrier is overcome, the resistance drops allowing for more current flow and voltage drop. It's kind of like overcoming the starting friction in a mechanical system, except on a chemical basis.

Our experiments will confirm this part of the curve in a slightly different manner since the REEL Power software does not plot voltage against current, but rather voltage, current, and resistance against time. Nevertheless, it is interesting to see just how this part of the fuel cell operates.

Ohmic

Ohmic polarization occurs due to resistive losses in the cell. Since the MEA obeys Ohm's law ($V = IR$), the amount of voltage lost in order to force conduction varies linearly throughout this region. The Ohmic region is really the working area of the fuel cell where — with enough hydrogen and oxygen fuel — the voltage and currents remain constant for a given load. This is the flat part of the curve in **Figure 1**, and just like a modern lithium-ion or nickel metal hydride battery (Part 3), the output voltage and current remain stable over time as long as the load remains the same and fuel is available. Again, our experiments will illustrate and confirm this performance area.

Mass Transport

In this region, the reactants become consumed at greater rates than they can be supplied as the fuel begins to run out. Ultimately, these effects inhibit further reaction altogether, and the cell voltage and current drop to zero very rapidly.

There's a lot more chemistry in all three of these processes, but it's beyond the scope of this article. The main points to realize are that fuel cell behavior resembles a modern rechargeable battery and that its usefulness for powering electrical systems is generally equivalent to batteries.

The Fuel Cell's Power Curve

Another interesting thing about the fuel cell's performance is the power curve. **Figure 1** shows it to be nearly linear right up to when the fuel runs out, which means that the fuel cell can supply a load (an electric motor, for instance) strictly based on demand. No power is lost or expended "getting to" the maximum power point. In contrast, internal combustion engines operate most efficiently only at full load and exhibit a rapid decrease in efficiency at partial loading. This fact alone may create the basis for the popularity of the electric car once it has a chance to mature in the marketplace — whether it's powered by batteries or a fuel cell, or a combination of both.

Fuel Cell Efficiencies

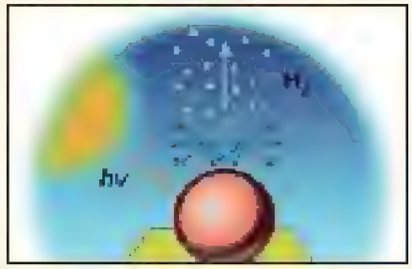
A fuel cell's efficiency — basically the ratio of power out versus power in, or fuel consumed versus fuel supplied — can be defined and measured in two ways. As mentioned previously, one is called Energy Efficiency and the other is Faraday Efficiency. The symbol used to express efficiency is generally the Greek lower-case letter, eta (η). We'll measure both efficiencies in our experiments, but here's a preview of what we'll be measuring.

Energy Efficiency

The Energy Efficiency of a fuel cell is the ratio of the electricity produced by the consumed hydrogen, compared with the calculated theoretical energy contained in the consumed hydrogen; this is expressed as a percentage. To figure this out, we need to express a few equations in chemical nomenclature in order to determine the theoretical energy contained in hydrogen. So, get out your high school chemistry book if you're not familiar with some of the following chemistry terms.

Breakthrough Producing Hydrogen from Water and Sunlight

Sunlight + Water = Hydrogen Gas



Led by Dr. Thomas Nann, scientists at the University of East Anglia report a breakthrough in the production of hydrogen from water using the energy of sunlight. Amidst all the hype about a potential hydrogen economy, one of the big questions has been whether sufficient hydrogen can be produced without using yet more energy to create it (the main stumbling block thus far). Typical production methods include stripping hydrogen from other fuels like methane (called reforming) or using electrolysis to split the hydrogen out of water (as we have done). But with efficiencies between 20% and 40% for producing energy from traditional photovoltaic processes, the hydrogen economy cannot be solar powered. Or can it?

Dr. Namm's group has discovered a more efficient way to do this using a gold electrode coated with nanoclusters of indium phosphide to absorb incoming photons of light (that is the wavy line marked "hv" in the image). The nanoclusters then pass electrons liberated by the sun's energy into an iron-sulfur complex which acts like a match-maker between the negatively charged electron and a hydrogen proton in the surrounding water molecules. Gaseous hydrogen is generated and the net result is a 60% efficiency for a process in which hydrogen is produced from water by the photons in light that strike a specially designed submersed electrode. The next step is to demonstrate the process with cheaper materials. The scientists report there is no special reason to use gold or platinum — which was used as the second electrode to complete the circuit — other than these noble metals happened to be lying about the lab (some lab!).

Source: Christine Lepisto, TreeHugger.com with edits by John Gavlik.

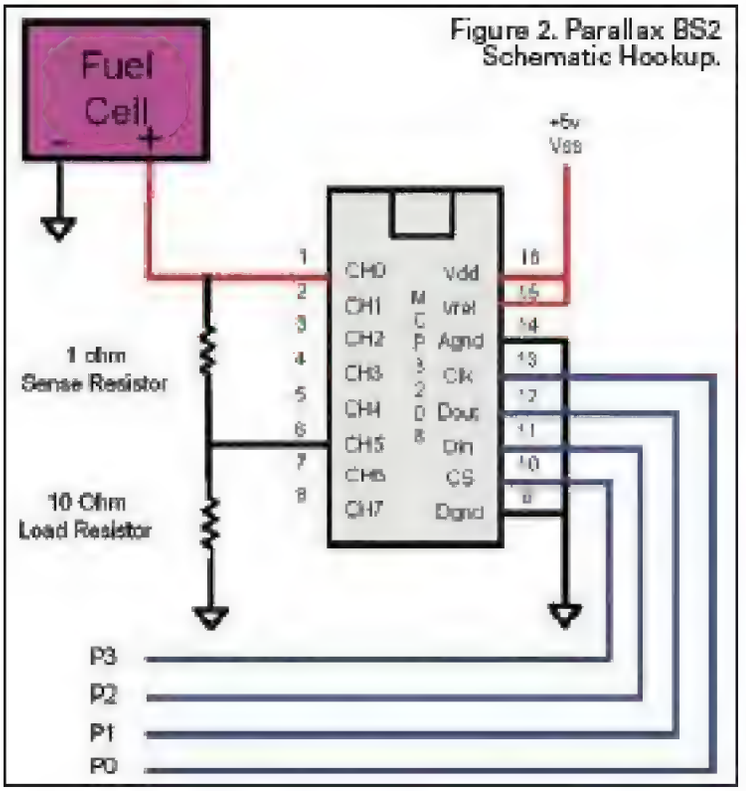


Figure 2. Parallax BS2 Schematic Hookup.

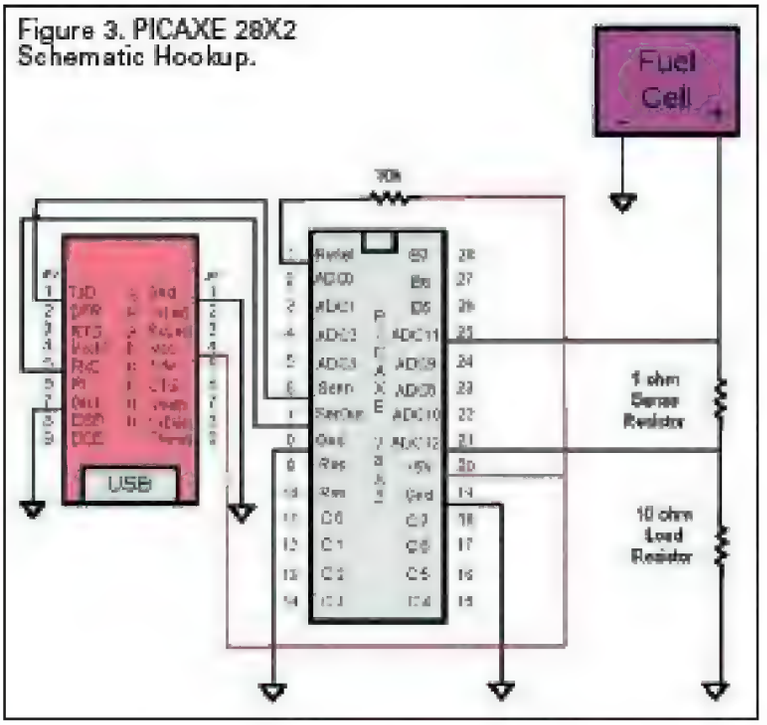


Figure 3. PICAXE 28X2 Schematic Hookup.

The energy content of hydrogen is calculated by using the amount of energy given off when hydrogen is combusted. This is a given value of 286,000 Joules/mol of hydrogen (exothermic; i.e., a chemical reaction where heat is lost). This is called the molar enthalpy of hydrogen at standard temperature and pressure. We also have the given value for the amount of space H2 takes up per mol. H2 has a molar volume of 24,000 mL/mol and an energy content of 286,000 Joules/mol (1 Joule = 1 watt-second). Use the following equations to calculate the Energy Efficiency (η E).

η E = Electrical energy in Joules of H2 / Energy content of consumed H2, where:

- Electrical energy in Joules H2 = E (average) x I (average) x time (s)
- Volume of H2 consumed in mL/24,000 mL/mol, therefore ...
- Energy content of consumed H2 (theoretical) = xxx mol H2 * 286,000J/mol (where xxx is the number of H2 mols consumed).

Faraday Efficiency

The Faraday Efficiency is a percentage that tells us how much of the hydrogen gas is being used for intended electrical energy production and how much is lost to other factors. It is the ratio between the theoretically calculated volumes of hydrogen consumed by the load *at a certain current* versus the experimentally calculated volume of hydrogen consumed. The equation for Faraday Efficiency (η F) is:

η F= H2 Volume (theoretical) / H2 Volume (experimental)

This phenomenon was originally understood through Michael Faraday's work and expressed in his laws of electrolysis. In effect, it describes the efficiency with which electrons (charge) are transferred in a system to facilitate an electrochemical reaction. The word "Faraday" in this term has two interrelated aspects.

First, the historic unit for charge is the faraday (look at any capacitor's charge value if you're not sure), but it has since been replaced by the coulomb — a unit of electrical charge equal to the amount of charge transferred by a current of one ampere in one second. Secondly, the related Faraday's constant correlates charge with moles of matter and electrons.

Now to the Experiments

Given this background information, we can now proceed with the experiments in confidence that we know what we want to measure and expect to see. We'll be using both the Parallax BS2 and PICAXE 28X2 microcontrollers in our test beds. **Figure 2** and **Figure 3** show their initial schematic hookups. You can find the complete experiments

Horizon Hydrocar

For these experiments, we're using the Horizon Hydrocar reversible fuel cell and storage cylinders, so make sure the car's motor switch is turned OFF and that the wires going to the motor are not connected.

The Horizon Hydrocar can be purchased online from the *Nuts & Volts* Webstore at [redacted] or call our order desk at [redacted].

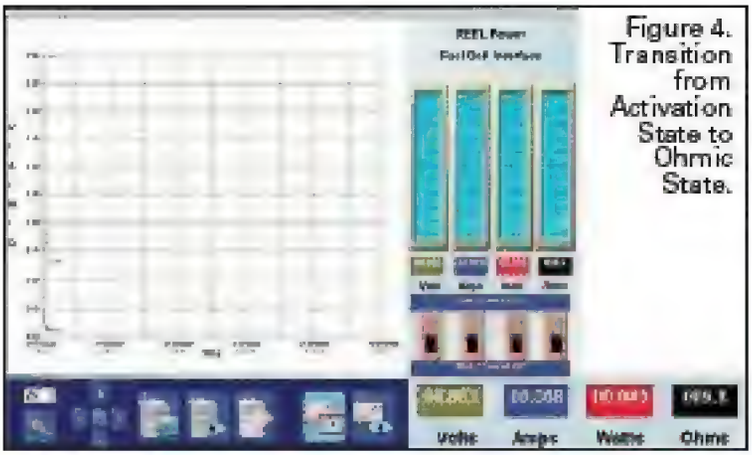


Figure 4. Transition from Activation State to Ohmic State.

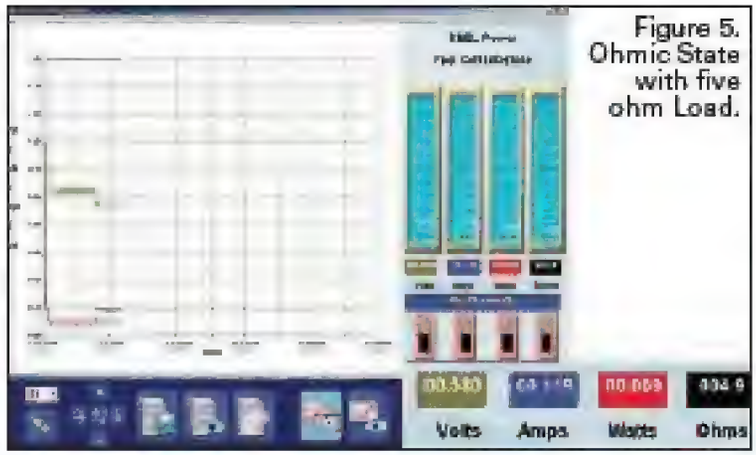


Figure 5. Ohmic State with five ohm Load.

including detailed hookup information and procedures for these two micros at **www.learnonline.com** → Experimenter Kits → Parallax or PICAXE → Hydrogen Experiments → Polarization Characteristics and Fuel Cell Efficiencies. You'll also need the REEL Power graphic software to witness what's happening on your computer, and you'll need a reversible fuel cell like the one in the Horizon Hydrocar (**sidebar**) or your own reversible PEM fuel cell. Both of these are available in the *Nuts & Volts* store at **www.nutsvolts.com**.

Polarization State Experiment

Let's start by measuring the polarization states. Set up the Test Bed per the instructions in the experiments on the LearnOnLine website and create 8 ml of hydrogen (H_2). Attach the fuel cell to the Test Bed and witness the rapid transition from the Activation to the Ohmic state as shown in **Figure 4.** With the 10 ohm load, this occurs quite quickly; a higher resistance value will cause it to take longer and, of course, a lower resistance will be even faster as you'll see next.

Figure 5 shows the initial entry into the Ohmic state where voltage (green plot line) and current (blue plot line) are flowing to create a bit of power (red line). Notice the flat plots for these data; it illustrates the linearity of the fuel cell's ability to supply steady current and voltage for a given load – 10 ohms, in this case. Now add another 10 ohm resistor in parallel with the first one and notice the increase in current and power with an attendant decrease in voltage. This will dissipate the hydrogen more quickly and get us into the Mass Transport state even sooner. **Figure 6** and **Figure 7** show the plots for three 10 ohm resistors in parallel (3.3 ohms) and four 10 ohm resistors in parallel (2.5 ohms). Again, notice the jump in current and power along with a decrease in voltage as each resistor is added to the load. Again, the feature to realize is the flatness of the plots at each load level. This mimics a rechargeable battery to a tee.

Figure 7 shows the entry into the Mass Transport state where the hydrogen fuel begins to run out. With a diminishing volume of hydrogen, the fuel cell cannot produce enough current to supply the 2.5 ohm load so something has to give. In this case, it's the voltage that starts to drop. **Figure 8** shows the Mass Transport state in full swing as the voltage, current, and power drop quickly due to the lack of hydrogen fuel. The computer plots confirm the polarization curve described in **Figure 1** except that the computer plots show voltage, current, and power plotted against time rather than voltage plotted against current. Nevertheless, the voltage part illustrates the three polarization states quite accurately. You are encouraged to repeat this experiment using a100 ohm potentiometer instead of the individual 10 ohm resistors to better see how the fuel cell performs over all three regions at different loads. Start with the potentiometer at maximum resistance, then decrease the resistance values to verify other current settings along with their attendant voltage and power readings.

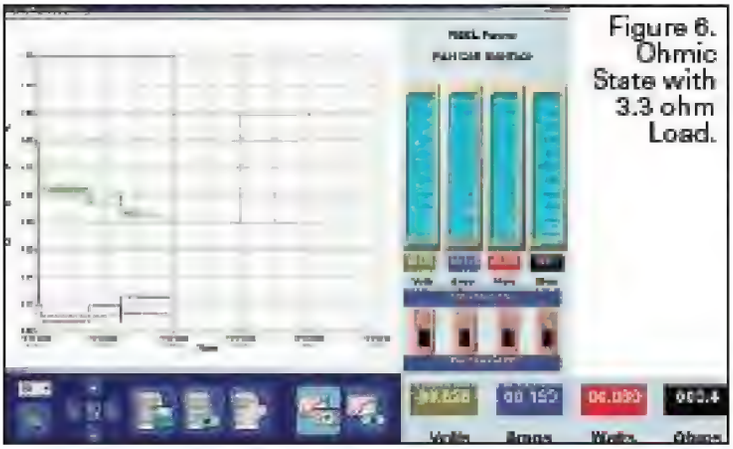


Figure 6. Ohmic State with 3.3 ohm Load.

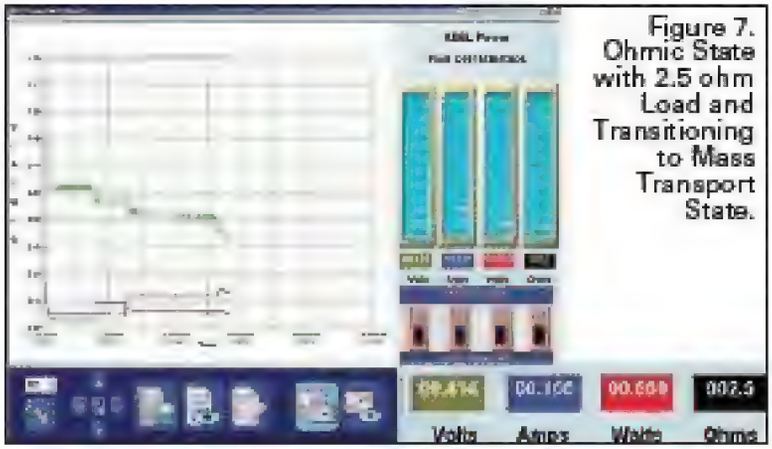


Figure 7. Ohmic State with 2.5 ohm Load and Transitioning to Mass Transport State.

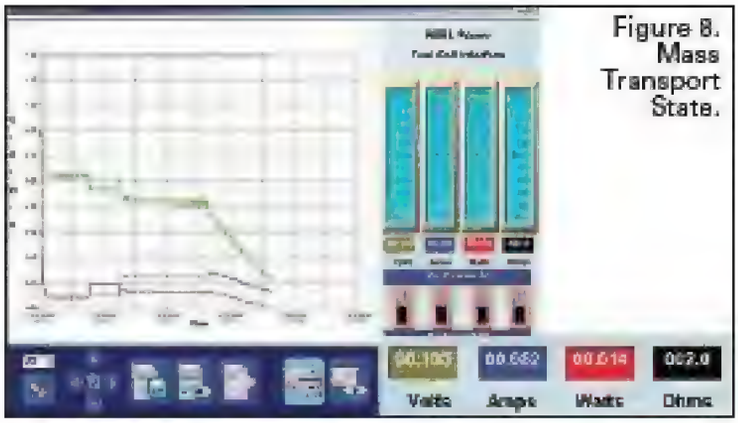


Figure 8. Mass Transport State.

Figure 9. Beginning and Ending Electrical Data for Five Minutes.

Efficiency Experiments

Now, let's determine our fuel cell's efficiencies (Energy and Faraday) by first generating 6 ml of hydrogen this time. We want to set up the Test Bed with a five ohm load (two 10 ohm resistors in parallel or equivalent). Then, we need to time the rate of hydrogen consumption with a wristwatch or your computer's clock. Start by generating the 6 ml of hydrogen; when you're ready, connect the fuel cell to the Test Bed and begin timing the process. We want to allow the hydrogen to be consumed over exactly five minutes or 270 seconds.

When the time is up, disconnect the fuel cell from the Test Bed and visually measure the remaining hydrogen left in the storage cylinder. During the timing, record both the starting and ending voltages and currents. **Figure 9** shows the start and stop values that I measured; your data may differ. Now, let's plug in some numbers to see how efficient our fuel cell performed.

Energy Efficiency Calculations

The energy efficiency of a fuel cell is the ratio of the electricity produced by the consumed hydrogen compared with the calculated theoretical energy contained in the consumed hydrogen (expressed as a percentage). In order to compute the required values, the average voltage (E) and current (I) must be determined. The averages are computed between the readings at time zero and at 270 seconds. **Table 1** illustrates these averages based on the data taken. Your values may be different.

Time	E (volts)	I (amps)	H2 (ml)
1 second	0.580	0.124	6 (starting)
270 seconds	0.497	0.114	1 (remaining)
	0.539 (avg)	0.119 (avg)	5 (consumed)

Table 1. Averaging Readings.

Entering these values into the equations:

Electrical energy in Joules H2 = E (average) x I (average) x time (seconds)
Electrical energy in Joules H2 = 0.539 x 0.119 x 270 = 17.3 J

Therefore, the volume of H2 used can be found as:

Volume of H2 consumed in mL / 24,000 mL/mol = mol of H2
5 mL / 24,000 mL/mol = 0.00021 mol H2

The energy content consumed H2 is given by:

Energy content of consumed H2 (theoretical) = mol H2 x 286,000J/mol
Energy content of consumed H2 (theoretical) = 0.00021 x 286,000 = 59.6 J

Energy efficiency can be computed as:

η E = Electrical energy in Joules H2 / Energy content of consumed H2 (theoretical)
η E = 17.3 / 59.6 = 0.2903 x 100% = 29.03 %

Faraday Efficiency Calculations

Faraday Efficiency is the ratio between the theoretically calculated volume of hydrogen consumed by the load (at a certain current) and the experimentally calculated volume of hydrogen consumed. Faraday Efficiency is computed as:

η F = H2 Volume (theoretical) / H2 Volume (experienced) where ...

H2 Volume (theoretical) = [Electrical charge in Coulombs (C)] x [H2 Volume per mol]

Electrical Charge in Coulombs (C) = I (ave) x time (sec) = 0.119 x 270 = 32.13C
H2 Vol (theoretical) = (32.13 C / 193,000 C/mol) x 24,000 ml/mol = 3.99 ml

Therefore, the Faraday Efficiency we measured is:

η F = H2 Volume (theoretical) / H2 Volume (experienced)
η F = 3.99 / 5.0 = 0.798 x 100% = 79.8 %

A value like 79.8% efficiency looks pretty good, but it can be better or worse depending on the electrical current used in the experiment. If you care to, modify the experiment with a different load resistor and repeat it.

Fuel Cell Stacks

Now that you know what an individual fuel cell is capable of and how it performs, it's time to learn a little about fuel cell "stacks." That is, combinations of multiple fuel cells wired in series and parallel for more voltage and current capability (**Figure 10**). Again, this is like hooking up batteries or solar cells but with

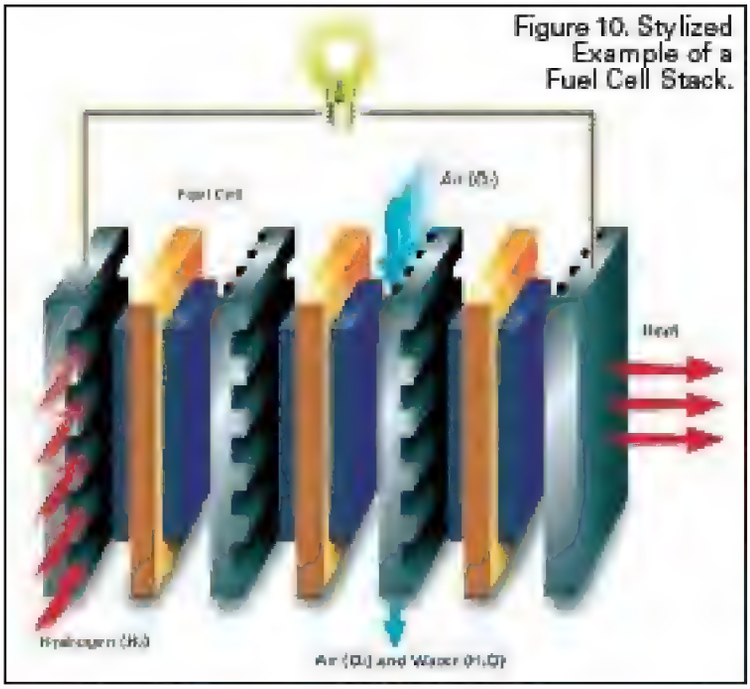


Figure 10. Stylized Example of a Fuel Cell Stack.

important differences relative to the fuel cell's unique physical geometry and fueling requirements. Depending on the fuel cell type (Part 10) and power requirements, each stack is different but the idea is still the same: Take something that generates about 0.5 volts at various currents (depending mainly on physical size) and scale it up to produce useful voltage, current, and power — just like a battery pack or solar module. Again, the similarities between fuel cells and batteries are amazingly close and, I guess, we can throw in solar cells, as well.

Fuel cell stacks are used for stationary, portable, and mobile applications. As of this writing, the most hyped of the stationary fuel cells is the Bloom Box (**Figure 11**). The Bloom Box is a solid oxide fuel cell stack that purports to be the solution for independent power for small homes to large buildings and everything else in between; it uses anything from natural gas to bio gas for a fuel source. Right now, it's very expensive and big and is only capable of powering large facilities like the Google headquarters and similar installations. If it can be scaled down to a smaller size, it may be able to power homes, but this is yet to be realized even in operational prototype form.

On the other end of the size and power spectrum of fuel cell stacks, you'll find a few that can power your cell phone directly or, at least, supply power to charge your cell phone's battery. MBI Micro has one that may be something you're after (**Figure 12**). The company's Mobion, 100% methanol fed, passive DMFC technology has been demonstrated in fully-functional prototypes and concept models in three primary product directions: external cord-free rechargeable power packs; attached fuel cell power sources; and embedded micro fuel cell designs. They (correctly) claim that your lithium-ion battery loses its charge capacity after a few years, so why not replace it with a fuel cell instead. However, who keeps their cell phone much over two years these days, and who wants to carry around a bottle of methanol to recharge your cell phone? (Try getting it past the TSA at the airport and see what happens.) Nevertheless, it looks like it can be done and it's a neat concept.

For mobile fuel cell stacks, Honda has one for its FCX Clarity car that is as functional and sleek as the car itself

Figure 11. Bloom Box Fuel Cell Installation *(photo credit Bloomenergy)*.

(**Figure 13**). For mobile applications, fuel cell stacks and the fuel itself must be designed for both performance and safety in mind, and Honda has done both very well. Honda has been the pioneer for many emerging technologies like robotics (Azimo), hybrid cars (the Insight), and now fuel cell powered vehicles. Hopefully, the Hydrogen Highway initiatives will occur to make the FCX a reality.

Summary

This time, you learned more about the essentials of how a fuel cell works and what can be done with them in terms of fuel cell stacks. You'll need this background information for our next fuel cell article. In it, I'll put our fuel cell powered Hydrocar through the paces to see how we can apply most of what we've learned about fuel cell technology to a neat mobile fuel cell project. So until next time, conserve energy and stay green. **NV**

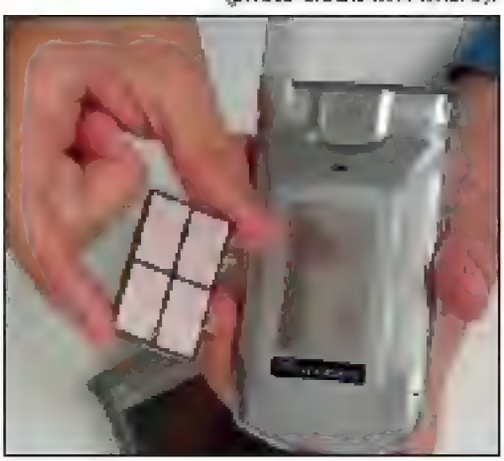


Figure 12. Cell Phone Fuel Cell *(photo credit MTI Micro)*.

Figure 13. Honda FCX Clarity Car and Internal Fuel Cell Stack *(photo credit Honda Motor Co.)*.

PICAXE PRIMER

SHARPENING YOUR TOOLS OF CREATIVITY

BY RON HACKETT

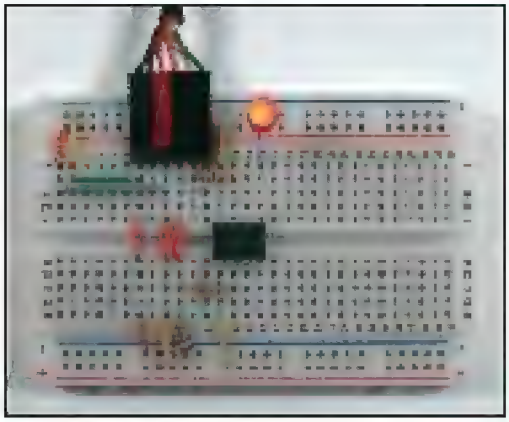
USING THE AXMATE POWER & PROGRAMMING ADAPTER

In this month's installment of the PICAXE Primer, we're going to construct a simple "AxMate" adapter that provides all the necessary breadboard connections for powering and programming a PICAXE project. The AxMate adapter simplifies the required connections to a breadboard-based project, and its small size maximizes the space that's available on a standard breadboard for your actual PICAXE circuitry.

If you are a *Nuts & Volts* subscriber, you're probably aware of the Arduino line of microprocessors. Arduinos may not be as inexpensive or as easy to program as PICAXE processors, but they do have some very interesting and powerful features. For example, most Arduino projects can be implemented by using a simple six-pin USB interface that provides all the necessary connections to power and program an Arduino circuit. The USB-to-serial IC that is used in an Arduino programming adapter is the FT232R from Future Technology Devices International, Ltd. This is the same chip that's used in the PICAXE AXE027 USB programming cable, so when I first became aware of the Arduino's single-cable breadboard connection, I naively thought that I could simply use the Arduino cable to power and program my PICAXE projects.

Pin	Color	Signal
6	Green	RTS#
5	Yellow	RxD
4	Orange	TxD
3	Red	+5V
2	Brown	CTS#
1	Black	Gnd

■ FIGURE 1. Pinout for the FTDI USB to Serial Cable.



■ FIGURE 2. Breadboard Setup to Test the FTDI Cable.

Figure 1 presents the pinout of the FTDI six-pin cable that I purchased from Mouser.com in order to try it with a PICAXE project. The CTS# and RTS# lines are both handshaking signals that are not used for PICAXE programming, so I just connected the +5V, Gnd, RxD, and TxD pins to a simple 08M "Hello World" project as shown in **Figure 2**. Note that the directionality of the TxD and RxD labels on the FTDI cable refer to the cable's "point of view."

In other words, the cable's TxD line should be connected to the 08M's SerIn (RxD) pin, and the cable's RxD line should be connected to the 08M's SerOut (TxD) pin. Also, the cable's TxD and RxD lines have already been converted to 5V TTL levels, so the resistors in the circuit may not actually be necessary. However, I didn't want to risk destroying anything so I included them just to be sure. As you can see in **Figure 2**, I painted a red stripe on the +5V pin to make sure I don't accidentally insert the cable's connector upside-down. Also, it's necessary to connect the cable's +5V and Gnd lines to both power rails on the breadboard.

After double-checking all the breadboard connections, I used the Programming Editor to download a simple LED blinking program to the 08M. Perhaps I should say I "tried to use ..." because it didn't work. ProgEdit informed me that the hardware was not found! After re-checking all the connections, I tried several more times but just kept getting the same error message. I spent some time searching the archives of the PICAXE forum and soon discovered the problem: the AXE027 cable inverts the TxD and RxD signals, but the FTDI cable does not invert them. The documentation for the AXE027 cable includes a schematic that shows no indication of either signal being inverted. This led me to conclude that the inversion is somehow implemented within the FT232R IC itself, so I began searching the FTDI website for clues. It turns

out that FTDI provides a free utility program that makes it possible to configure the communication signals however you want.

When I first discovered the program, it was called "M_Prog" but the name was recently changed to "FT_Prog." It's available for download at www.ftdichip.com/Resources/Utilities.htm. FT_Prog is very simple to use. I was quickly able to reconfigure the FT232R IC to invert the TxD and RxD lines, and my "Hello World" program successfully downloaded to the 08M without any further difficulties.

FT232R-BASED USB TO SERIAL ADAPTERS

Before we get into the details of using the FT_Prog utility to reconfigure the FT232R IC, I want to mention some of the hardware alternatives. Subsequent to my original experiments with the FTDI cable, I have tried the same approach with three other FT232R-based USB to Serial adapters that are listed in **Figure 3**. All three of them were easily reconfigured to function properly with PICAXE circuits and each one has advantages in different situations. The SparkFun "Basic" board is the smallest of the three boards; the "USB BUB" board includes a small prototyping area that allows you to re-order the signals if desired; the larger SparkFun breakout board is required for one of the AxMate variations that I'll describe below. All three boards are less expensive than the FTDI cable but they all require an additional USB cable which (of course) is not needed for the FTDI cable.

There are two limitations to this approach that are important to keep in mind. First, the maximum current output of the FT232R chip is about 100 mA, so this type of supply isn't nearly as powerful as one based on the standard 7805 voltage regulator. Even so, 100 mA is more than enough power for the majority of small PICAXE projects, and the AxMate adapters are so simple to use and to move from one breadboard to another that I find myself reaching for an AxMate whenever I want to set up a new PICAXE circuit.

■ FIGURE 3. Selected FT232R USB to Serial Adapters.

USB to Serial Adapter	Vendor	Part Number
TTL-232R-5V Cable	Mouser.com	895-TTL-232R-5V
FTDI Basic Breakout Board	SparkFun.com	DEV-09115
USB BUB Board	ModernDevice.com	USB BUB Board
FT232RL Breakout Board	SparkFun.com	BOB-00718

The second limitation is that the FT_Prog utility only runs on Windows. However, if you're willing to pay the return postage, you can send me your FT232R cable or adapter and I'll reconfigure it and mail it back; just email me to make arrangements.

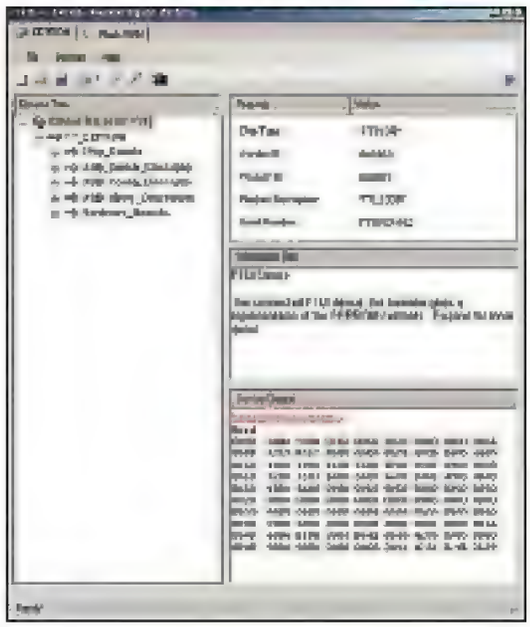
USING THE FT_PROG UTILITY

As I mentioned earlier, you can download the FT_Prog utility from FTDI. Be sure to read the note about the necessity of installing the Microsoft .NET Framework 2.0. Also, go to the "Drivers" page and download the drivers for your operating system. In the following list of directions for using FT_Prog to reconfigure your adapter, I used an FTDI cable but the process is the same for any adapter.

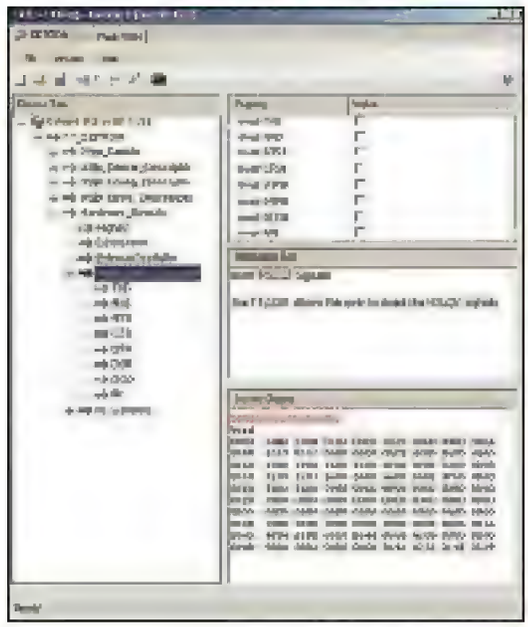
1. Install the necessary driver, connect your cable or adapter to a USB port on your PC, and Run the FT_Prog utility. Select "Devices" > "Scan and Parse" — you should see a window similar to **Figure 4**.
2. Double-click on the "Hardware_Specific" entry on the left, then single-click on "Invert_RS232_Signals" — you should see a window similar to **Figure 5**.
3. Click in the boxes for "Invert TXD" and "Invert RXD," and then select "Devices" > "Program" — you should see a window similar to **Figure 6**.
4. Click in the box on the left next to the device and then click the "Program" button.
5. To check that the IC has been reconfigured, just click on the "Invert_RS232_Signals" entry on the left. The TxD and RxD signals should now be inverted.
6. Quit the FT_Prog utility.

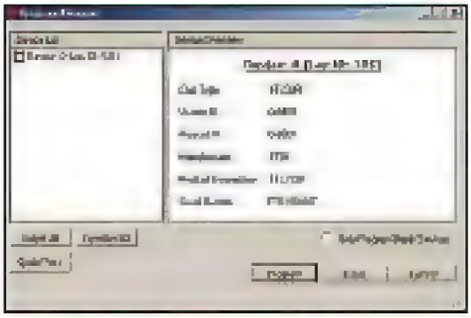
When you have reconfigured your adapter, use the breadboard layout presented earlier (**Figure 2**) to set up a simple "Hello World" circuit so that you can test your adapter. When you run ProgEdit, you will probably need to click the "Refresh"

■ FIGURE 4. FT_Prog Step 1.

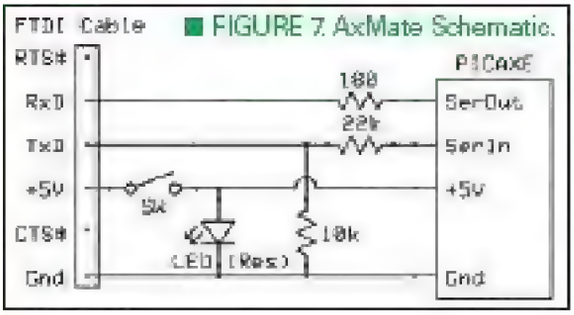


■ FIGURE 5. FT_Prog Step 2.





■ FIGURE 6. FT_Prog Step 3.



■ FIGURE 7. AxMate Schematic.

button in the Options window in order to see which COM port has been attached to your adapter. (The "Scan for USB Cable" option only works for the AXE027 cable.) When you have completed the setup in ProgEdit, download a simple LED blinking program to your 08M. If you have configured everything correctly, the program will download normally and the LED will begin to blink. If not, you will need to recheck everything (the adapter's configuration, the driver installation, and the circuit wiring).

CONSTRUCTING A SIMPLE AXMATE ADAPTER

The next step in our AxMate project is to construct a small adapter that includes the circuitry we just used to test the FTDI cable. The schematic for our AxMate adapter is shown in **Figure 7** and **Figure 8** contains the parts list (as usual, all the parts are available on my website; **www.jrhackett.net**). The stripboard layout is shown in **Figure 9** and **Figure 10** is a close-up photo of the completed adapter. Before we begin construction of the AxMate adapter, I need to clarify a couple of points. First, as you can see in the photo, the switch that I used is a little larger than the one that's included in the layout which results in it extending slightly beyond the boundaries of the stripboard. I built an early prototype using a smaller switch, but it was difficult to use so I decided to go with the larger one shown in **Figure 10**.

Also, if you look closely at the photo, you can see that the adapter actually consists of two pieces of stripboard in the "sandwich" arrangement that we have used in previous projects. The top piece of stripboard — which contains four traces with four holes each — is mounted upside-down so that it spans the two four-pin male headers. Its traces run perpendicular to the headers and are soldered to the short ends of each of the header pins. This arrangement results in the two headers having the same pinout, which we have used before. From left to right in the photo, the connections are as follows: +5V, Gnd, SerOut, and SerIn.

As usual, I have color-coded the pins to remind myself of the correct connections. I again painted a red stripe on the cable connector and a red dot on the right-angle male header to identify the +5V connections so that I don't accidentally insert the cable connector upside-down. Finally, you can see that I have made a small notch in the stripboard. This isn't really necessary; you could easily install the SerIn and SerOut jumpers first and then insert the stripboard into the breadboard. However, I prefer to be able to see the actual connections when the board is in place.

With the above points in mind, it's time to heat up the soldering iron and get to work! Read through the complete list of assembly instructions that follows to be sure you understand the entire procedure before assembling the board.

1. Cut and sand a piece of stripboard to the required size (six traces with eight holes each).
2. (Optional) Cut and sand a small "notch" in the stripboard that removes holes G5, G6, H5, and H6 as shown in the layout presented earlier in **Figure 9**.
3. Sever the trace on the bottom of the board at each of the points indicated in the layout of **Figure 9**.
4. Insert the jumper from F6 to F5 and solder it at F6, but not at F5 yet. Be sure to leave enough length on the bottom of the board at F5 so that the jumper can be extended to the header pin at F4 when we get to that step.
5. Insert the three resistors and solder the leads at D3, D6, E2, and E3, but not at G2 and H3 yet. Be sure to leave enough length on the bottom of the board at G2 and H3 so that the leads can be extended to the adjacent header pins when we get to that step.
6. Insert the bent leads of the six-pin right-angle male header from the top of the board at B1 through B6, and solder them on the bottom.
7. Insert the long ends of the pins of the two four-pin reverse-mountable male headers from the top of the board. Invert the board and headers and insert the short ends of the pins into a breadboard for support.
8. On the bottom of the board, bend and snip the two unsoldered resistor leads and the unsoldered jumper wire so that each one makes contact with the adjacent header pin as shown in the layout. Use a flat-bladed screwdriver to press the bent leads flat against the traces, and then solder the leads at F4, F5, G1, G2, H3, and H4.
9. Solder the remaining header pins **except** the pin at E4.
10. Flip the board right-side up again

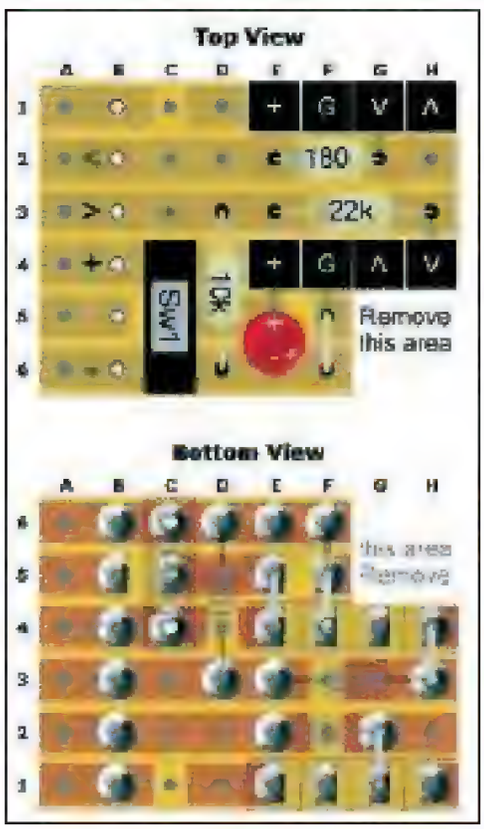
■ FIGURE 8. AxMate Parts List.

PART
Stripboard #1: 6 traces of 8 holes
Stripboard #2: 4 traces of 4 holes LED: 3mm, resistorized Switch: SPDT, 0.1" pin-spacing
Resistor: 180 ohms, 1/6 W Resistor: 10k 1/6 W Resistor: 22k 1/6 W
Headers (2): 4-pin mail, straight*
Header: 6-pin mail, rt. Angle
*Reverse-mountable

and insert the long ends of the male headers into a breadboard for support.

11. Place the inverted 4x4 piece of stripboard on the short ends of the header pins so that the pins protrude through the end holes of each trace (see **Figure 10**).
12. Solder the short ends of the pins to the 4x4 sandwich board. At this point, you may want to snip the protruding pins from the top of the sandwich and file them smooth — especially if you intend to paint them later.
13. Remove the board assembly from the breadboard and insert the resistorized LED as shown in the layout. (Be sure to observe the correct polarity.)
14. On the bottom of the board, bend the lead from E5 and snip it so that it makes contact with the header pin at E4. Press the lead flat against the traces and solder the leads at E4, E5, and E6.
15. Insert the switch and solder its leads at C4, C5, and C6.
16. On the bottom of the board, file all the cut leads smooth.
17. Clean the flux from the bottom of the board and allow it to dry.
18. Inspect the board carefully for accidental solder connections and other problems.

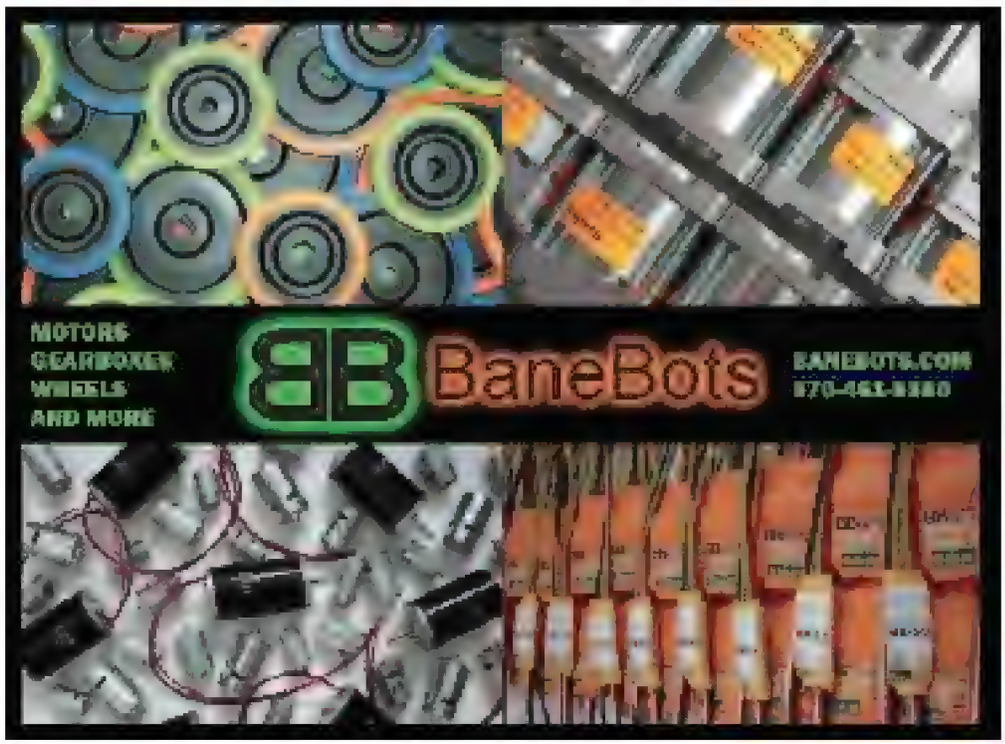
■ FIGURE 9. AxMate Stripboard Layout.



TESTING THE COMPLETED AXMATE ADAPTER

To test the completed AxMate adapter, simply insert it into the end of a breadboard (so that it straddles the center divider) and connect it to your computer with the FTDI cable or one of the USB to Serial adapters we discussed earlier. On the breadboard, make the connections as shown in **Figure 10**. Before you include the 08M, turn on the AxMate's switch and use a multi-meter to test the power and ground connections on both power rails.

When you're sure everything is



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correct, turn off the switch and connect the 08M as shown in **Figure 10**. Download the same LED blinking program we used earlier to test the FTDI cable. If the LED doesn't begin to blink, you will need to re-check the AxMate and breadboard wiring.

AXMATE VARIATIONS

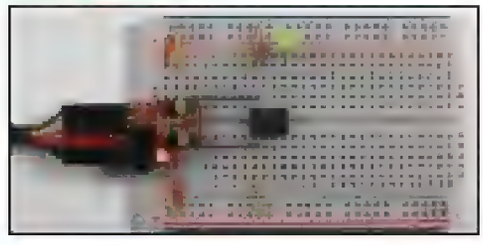
The AxMate approach to powering and programming PICAXE projects not only simplifies the necessary breadboard connections, it can also be incorporated into a wide range of adapters and project boards designed for specific purposes. **Figure 11** is a photo of four new AxMate printed circuit boards (PCBs) that are available on my website. The board in the upper-left quadrant of the photo is the PCB version of the stripboard we just constructed. The red PCB that's attached to it is the SparkFun Basic Breakout Board I mentioned earlier. The large board in the upper-right quadrant (the AxMate-18) is a complete 18-pin PICAXE project board. Pins underneath the board connect it to the upper power rail, so no additional power supply is necessary.

The board in the lower-left quadrant (the AxMate-SF) mates with the SparkFun FT232RL Breakout Board; it includes an on-board jumper that can switch the breadboard power supply from +5V to +3.3V for low voltage projects. Finally, the board in the lower-right quadrant (the AxMate-RE) contains a complete +5V regulated power supply, as well as the standard stereo connector that accepts the AXE027 USB programming cable.

This approach is suitable for projects that require more than a 100 mA supply or for users who would rather not switch from their AXE027 cable to a different USB to Serial adapter. I'm also working on an AxMate-08 board and an AxMate-14 board which will be added to the AxMate line in the next couple of months.

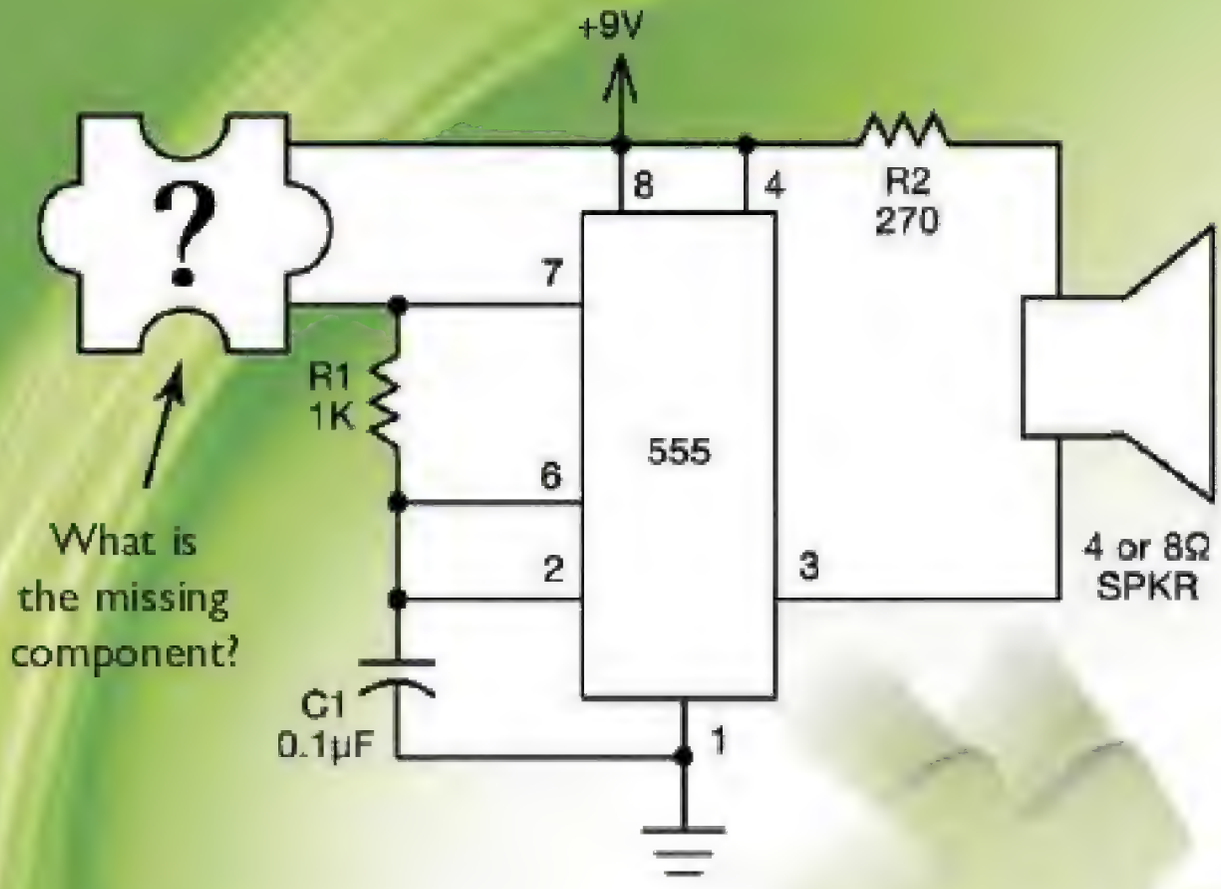
In addition to my recent involvement (a.k.a., obsession) with the AxMate boards, I have been working on a couple of possible projects for the next installment of the Primer. At this point, I haven't yet settled on a final choice, so I'll leave it as a surprise. See you then ... **NV**

■ FIGURE 10. AxMate Installed on a Breadboard.



■ FIGURE 11. AxMate Variations.

Can You Guess the Missing Component?



Amateur electronic musician Joe Rhythm is planning a one-man video concert that he plans to post on YouTube. Controlling his array of instruments requires both hands and he wants to build a pressure-sensitive tone generator that he can control with a free finger or even an elbow or foot. Joe quickly whipped up a simple tone generator using parts from his bench stock. Since there wasn't enough time to order a pressure sensor, he improvised by making one from materials he had on hand. What did he use? Go to www.Jameco.com/search6 to see if you are correct and while you are there, sign-up for our free full-color catalog.

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BY FRED EADY

ZEROG GOES USB

The ZeroG - PIC24FJ128GA006 Trainer project sparked quite a bit of *Nuts & Volts* reader interest. In fact, the ZeroG design stirred up so much email dust that I was compelled to offer the ZeroG - PIC24FJ128GA006 Trainer as a kit in the EDTP web store. It seems that our Design Cycle USB discussions have been popular with the *Nuts & Volts* readers, as well. So, this month we're going to take the ZeroG Trainer basic design, remove the ZG2100M Wi-Fi module, replace the original PIC24FJ128GA006 with a USB-enabled one, do some minor modification work on a new printed circuit board, and add a USB portal.

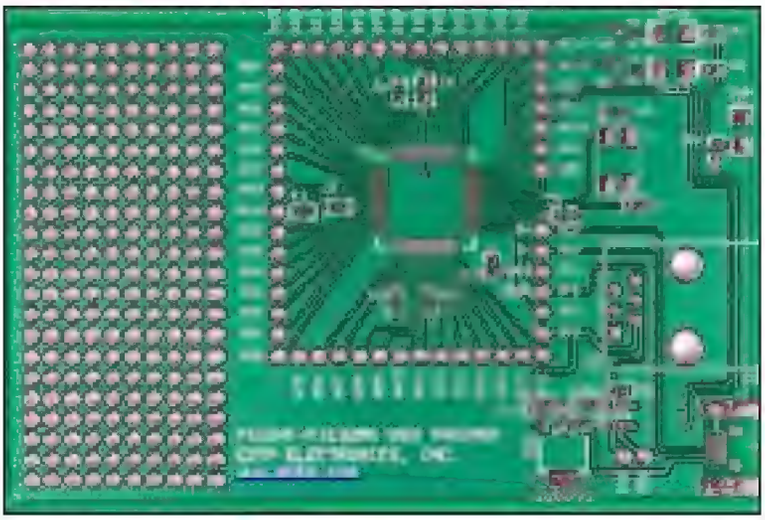
THE MICROCHIP PIC24FJ256GN106

The PIC24FJ256GB106 is a 16-bit USB v2.0-compliant microcontroller. To make this USB-enabled design easy for you to assemble, I've chosen this PIC for its high level of availability, low cost, and low pin count. As the numbers in its name imply, the PIC24FJ256GB106 is the largest microcontroller of the smallest PIC24FJxxxGBxxx series in terms of internal program memory. Sporting only 64 pins, the PIC24FJ256GB106 internals include 256K of high endurance program Flash and 16K of SRAM.

Like other members of its family, the PIC24FJ256GB106 I/O subsystem is based on a set of remappable peripherals. This PIC has 29 remappable pins which can be assigned to digital-only I/O pins using its peripheral pin select feature. Remappable I/O includes general-purpose timer clock inputs and timer-related peripherals such as input capture and output compare. Serial communications I/O pins tied to UART and SPI portals are also remappable. External interrupt inputs and comparator module outputs are eligible for remapping, as well. Note that you can't find a dedicated UART pin in **Figure 1**. However, you can find dedicated I²C and RTCC pins. Basically, any peripheral I/O pins that you can readily identify are not remappable.

The PIC24FJ256GB106 does a bunch of things with USB that we won't cover in our USB discussion. For instance, if your design requires it, the PIC can act as a low speed or full speed USB host. Although we won't use its host mode capability, we will take advantage of everything else USB that this PIC offers. The PIC24FJ256GB106's USB support is total to the point that all we need to do to tap into its USB potential is add a USB connector and a 3.3 volt regulator to our design.

■ PHOTO 1. The PIC24F/PIC32MX USB Trainer PCB is designed to integrate with a perfboard or dedicated external PCB with standard 0.1 inch headers.



SPEAKING OF DESIGNS

Turn your attention to **Photo 1**. The deceptively simply printed circuit board (PCB) is the base component of a PIC24F/PIC32MX USB Trainer. If you're wondering how PIC32MX got into the PIC24F/PIC32MX USB Trainer's moniker, compare **Figure 1** to **Figure 2**.

This is a good time to show you how peripheral pin select allows the PIC32MX and PIC24FJ256GB106 microcontrollers to lay eggs in the same nest. Note that in **Figure 2** PIC32MX pins 31 and 32 can be configured as UART I/O. Those same PIC24F/PIC32MX USB Trainer I/O pins in **Figure 1** are remappable (RP10 and RP17). Recall that we can use the PIC24FJ256GB106's peripheral pin select feature to remap UART I/O. The same UART

peripheral pin select magic will also work on pins 5, 6, 50, and 51 of the PIC. This 16-bit/32-bit motor swap capability reminds me of the good old days when guys were dropping 454 cubic-inch engines into Chevy Vegas!

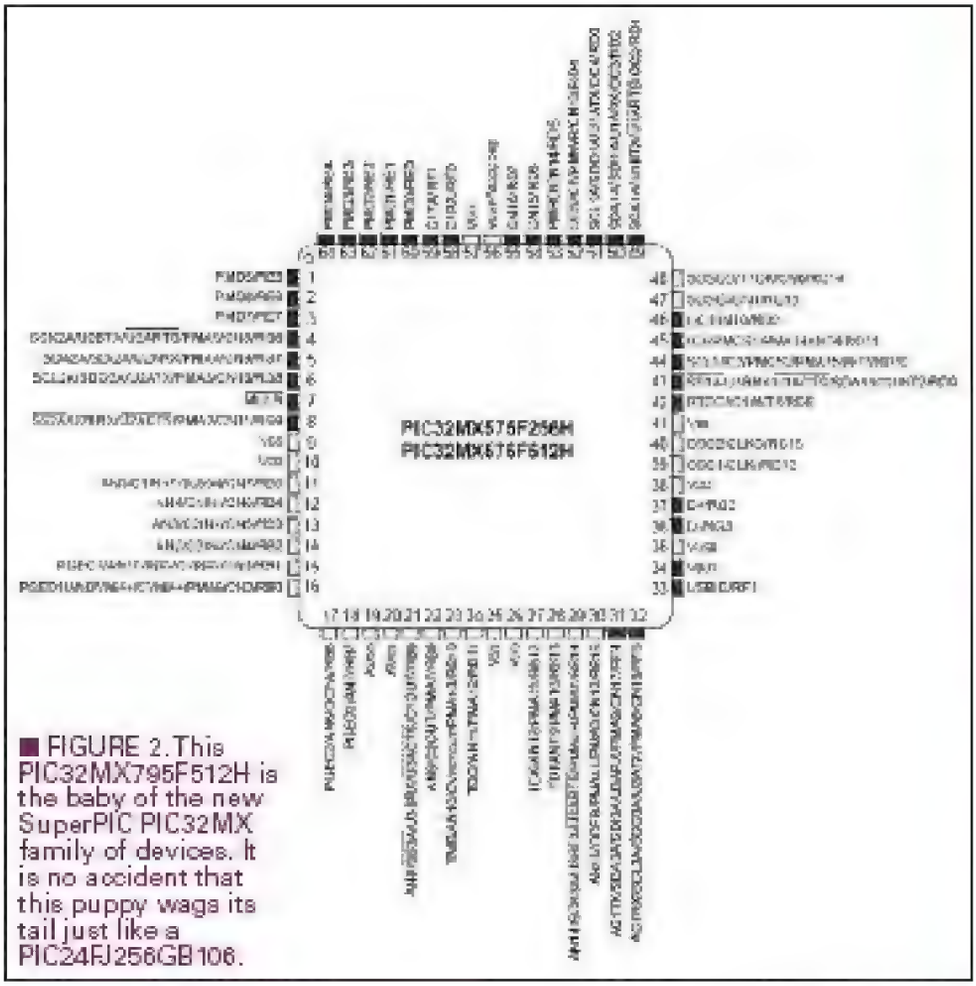
An 8 MHz crystal is all we need to generate all of the necessary CPU, peripheral, and USB clocks. The 8 MHz primary oscillator signal is fed to the PIC24FJ256GB106's USB PLL which produces the absolutely necessary 48 MHz USB clock. Our PIC24F/PIC32MX USB Trainer design uses an external 8 MHz crystal. However, we can also generate the 48 MHz USB and all of the CPU and peripheral clocks using the PIC24's internal 8 MHz oscillator. Our 8 MHz crystal-controlled clock is also used to feed the 4x PLL that drives the 32 MHz CPU clock.

The host USB portal supplies +5 volts DC in addition to the USB signals D+ and D-. The PIC24FJ256GB106 is a 3.3 volt microcontroller, so we'll need to add a voltage regulator to our design. I've chosen a Microchip TC1262-3.3 for the job. The TC1262-3.3 only requires a pair of 4.7 µF ceramic capacitors for stable operation and is capable of 500 mA operation.

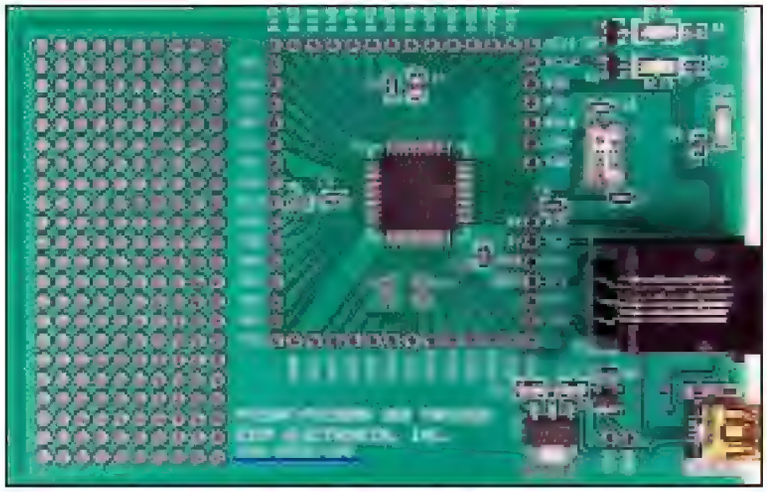
It's a sure bet that one of the peripheral devices you'll want to hang onto the USB Trainer base design will require a five volt power rail. A common LCD is a good example of a highly desirable five volt peripheral device. However, you won't want to fire up the Trainer with a five volt load until you have performed the proper USB initialization processes. Before drawing significant amounts of current from the USB power portal, you must get permission from the USB hardware. That's where the TPS2041BDBVT's microcontroller-controlled active-low EN (Enable) input comes into play.

Once our USB session has enumerated and enters the CONFIGURED state, we have the ability to turn on the voltage spicket (spicket is Southern speak for the output of a faucet or alcohol condensation unit) to the five volt peripherals via the TPS2041BDBVT solid-state switch. While we're discussing voltages, the PIC24FJ256GB106's internal 2.5 volt regulator requires the 10 µF ceramic filter capacitor and its

■ FIGURE 1. The really neat thing about the PIC24FJ256GB106's peripheral pin select feature is that we can place the remappable peripherals in the same pin locations as the dedicated peripherals on other 16-bit and 32-bit microcontrollers.



■ FIGURE 2. This PIC32MX795F512H is the baby of the new SuperPIC PIC32MX family of devices. It is no accident that this puppy wags its tail just like a PIC24FJ256GB106.



■ PHOTO 2. Simple, elegant, powerful, and cheap thanks to reusable hardware and firmware technology.

companion power supply bypass capacitor that are tied in parallel to the PIC's VCAP pin.

The PIC24's I/O pins can source and sink up to 18 mA each. To ease the burden on the PIC's I/O subsystem, I've buffered visual indicators LED1 and LED2 with a couple of NUD3105 MOSFET switches. The NUD3105 devices are designed to drive small inductive loads up to 500 mA. Note the absence of series gate resistors for Q1 and Q2 as the required gate resistors are internal to the NUD3105 components. If you decide to drive inductive loads with the NUD3105s, the freewheeling diodes are also integral to the devices.

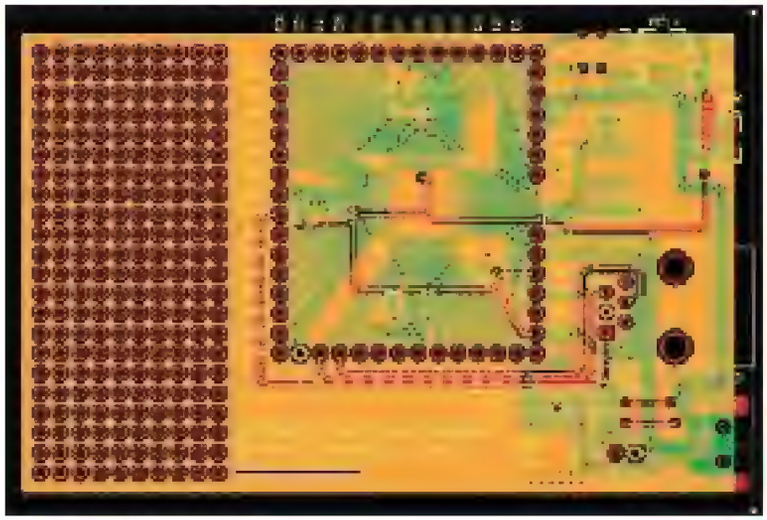
ASSEMBLING A PIC24F/PIC32MX USB TRAINER

Every electronic component mounted on the assembled Trainer you see in **Photo 2** can be mounted and soldered by hand. The entire USB Trainer design consists of 27 easy-to-find electronic components that can be obtained from Mouser (www.mouser.com).

In the recent past, I've received emails from readers informing me that some of my Design Cycle projects are a bit too pricey. So, to keep the costs down and Design Cycle readers happy, the PIC24F/PIC32MX USB Trainer is built upon an inexpensive two-sided ExpressPCB PCB. Many of you that will build your own version of the PIC24F/PIC32MX USB Trainer have a specific set of external peripheral devices that you will add to the base Trainer design. With that thought in mind, note the absence of additional pushbuttons, RS-232 converters, or LCDs in the base design. The idea is to allow you to add only the peripherals you need for your application without having to work around peripherals your application will never use.

Due to its low parts count, the PIC24F/PIC32MX USB Trainer is simple enough to be assembled using only a schematic diagram. To further ease your assembly burden, the Trainer's PCB silkscreen component identification layout shown in **Screenshot 1** matches the component identification found in **Schematic 1.**

■ SCREENSHOT 1. The LEDs can be separated from the PIC24FJ256GB106's I/O pins by simply removing the trace jumpers between the PIC I/O pin and the MOSFET switch gates. The header pads surrounding the PIC will mate perfectly with an external board's pads laid out on 0.1 inch centers.



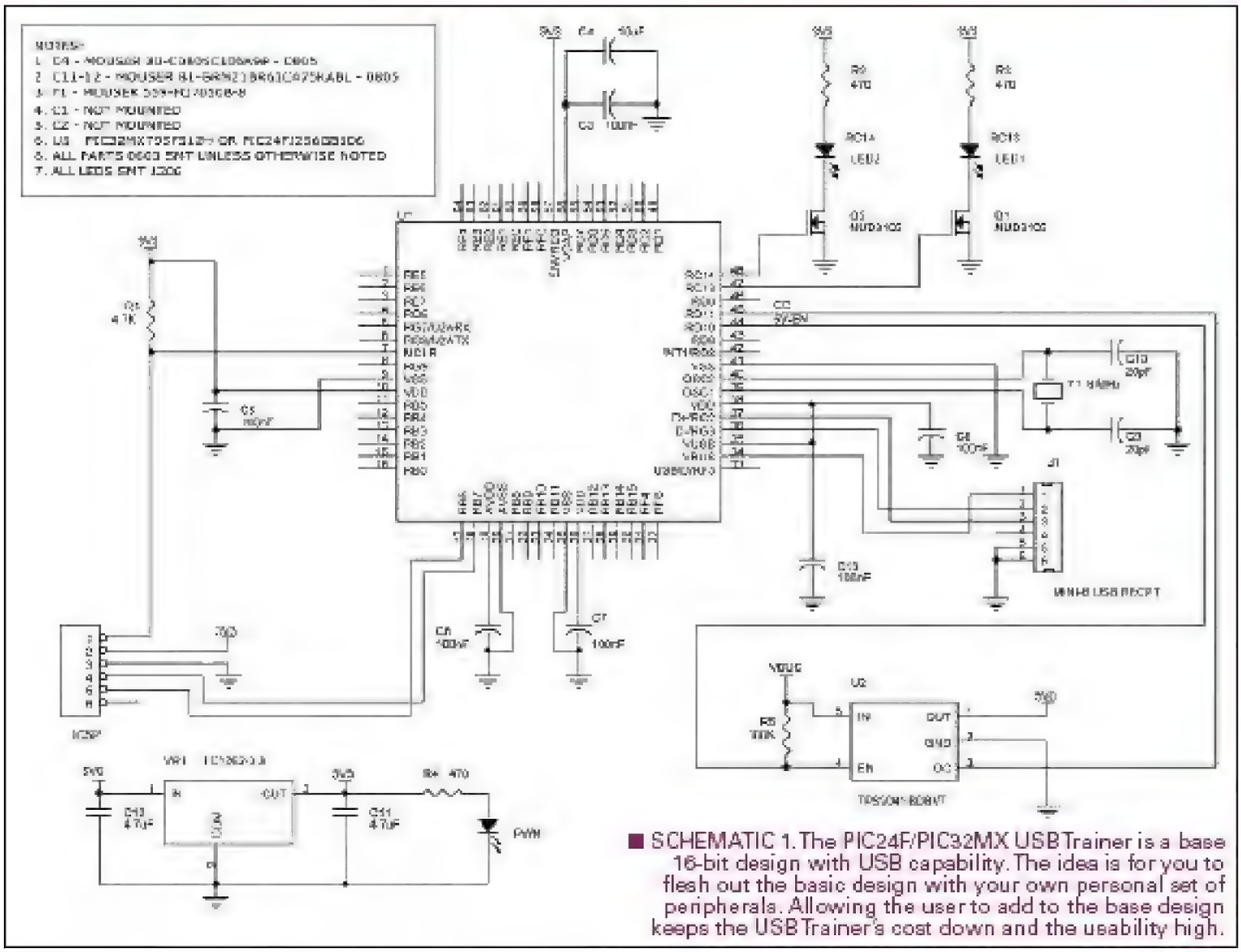
CODING THE PIC24F/PIC32MX USB TRAINER

Thanks to Microchip, coding the PIC24FJ256GB106 for USB duty is just as easy as assembling the USB Trainer hardware. The PIC24F/PIC32MX code is based on the Microchip USB libraries that are part of their Application Libraries v2010-02-09. Keeping with my low-cost mantra, these tools are free for a download. The compiler of choice for this project is Microchip's C30 which isn't free. I get loads of emails from readers asking if the free Lite compiler editions will run Design Cycle projects. That you'll have to determine for yourselves as there are an infinite number of peripheral configurations and applications that can or cannot be compiled with any particular C compiler. In other words, there are just some things that I can't test.

In that the USB stack is provided as a package, all we have to do to utilize the packaged tools is build or modify four user files. Modification of existing USB stack user files is the easier road to follow. A word of caution: DO NOT modify the USB stack package files under *any* circumstances. With that, let's begin our coding task with the *HardwareProfile.h* file:

```
#ifndef HARDWARE_PROFILE_H
#define HARDWARE_PROFILE_H

#include "HardwareProfile - EDTP 24F-PIC32MX USB
TRAINER.h"
#endif
```

That's it for the HardwareProfile.h file. Now, let's do the real work inside of the *HardwareProfile - EDTP 24F-PIC32MX USB TRAINER.h* file. The first order of business is to put our brand on this USB code:



■ SCHEMATIC 1. The PIC24F/PIC32MX USB Trainer is a base 16-bit design with USB capability. The idea is for you to flesh out the basic design with your own personal set of peripherals. Allowing the user to add to the base design keeps the USB Trainer's cost down and the usability high.

```
#ifndef EDTP_PIC24F_PIC32MX_TRAINER
#define EDTP_PIC24F_PIC32MX_TRAINER
```

Following our grand announcement of the hardware behind this code, you'll encounter the bootloader options. You'll find the bootloader code unchanged in our version of the HardwareProfile definitions. However, to inform the rest of the USB stack modules of our hardware's presence we must declare ourselves one more time as to who we are:

```
#define EDTP_PIC24F_PIC32MX_TRAINER
#define CLOCK_FREQ 32000000
```

As you can see, it's also a good time to tell the rest of the USB stack the speed of our CPU clock.

The LEDs included in the Trainer design serve a dual purpose. The status of the USB link enumeration is displayed in the LEDs. Once the link is up and running in the CONFIGURED state, the LEDs become part of the demo application which is part of the *main.c* file we'll look at later. In keeping with Fred Eady's First Law of Embedded Computing that "Nothing is free," to utilize the LEDs we must configure them in the USB stack's *USB TRAINER.h* file:

```
/** LED ************************************************/
#define mInitAllLEDs()  LATC &= 0x9FFF; TRISC
                        &= 0x9FFF;  //RC13, RC14

#define mLED_1          LATCbits.LATC13
#define mLED_2          LATCbits.LATC14

#define mGetLED_1()     mLED_1
#define mGetLED_2()     mLED_2

#define mLED_1_On()     mLED_1 = 1;
#define mLED_2_On()     mLED_2 = 1;

#define mLED_1_Off()    mLED_1 = 0;
#define mLED_2_Off()    mLED_2 = 0;

#define mLED_1_Toggle() mLED_1 = !mLED_1;
#define mLED_2_Toggle() mLED_2 = !mLED_2;
```

I chose to keep the USB stack's original LED definition names. That makes it easier to get a successful compile as you don't have to sift through the stack renaming the LEDs. As you'll see later, the *main.c* application and status routines will utilize the LED GetLED, On, Off, and Toggle macros.

The TPS2041BDBVT is not something that the USB

stack is expecting. So, it would be a good idea to mention it to the rest of the USB stack functions:

```
/** TPS2041BDBVT ********************************/
#define INIT_TPS() LATD &= 0xFFFF; TRISD &=
                   0xFBFF; //1111 1011 1111 1111
#define TPS_EN     LATDbits.LATD10
#define EN_5V()    TPS_EN = 0;
#define DIS_5V()   TPS_EN = 1;
```

If you take a look back at **Schematic 1**, the TPS2041BDBVT definitions and macros we just laid out make perfect sense. The CC current overload pin is not defined. If you plan on using the full 500 mA capability of the USB power source, you'll need to code a safety net routine that triggers on the output of the TPS2041BDBVT's CC pin. Theoretically, you should not be able to overrun the TPS2041BDBVT's current handling capability from the USB port. However, recall Fred Eady's Second Law of Embedded Computing which states "Never Assume Anything."

The *main.c* functions also include a routine that utilizes the AN0 analog-to-digital converter (ADC) input to read a voltage from the wiper of a 10K Ω potentiometer. If you wish to include this analog functionality in your application, here's the macro that is part of our *TRAINER.h* file:

```
/** POT ******************************************/
#define mInitPOT()  {AD1PCFGLbits.PCFG0 = 0;
AD1CON2bits.VCFG = 0x0;     AD1CON3bits.ADCS =
0xFF;     AD1CON1bits.SSRC = 0x0;
AD1CON3bits.SAMC = 0b00001;     AD1CON1bits.FORM
= 0b00;     AD1CON2bits.SMPI = 0x0;
AD1CON1bits.ADON = 1;}
```

That does it for our contributions to this file. The trick is to remember to identify any peripheral stuff you add to the design in your version of the *HardwareProfile.h* file set.

The USB stack's original PIC24FJ256GB106-based *usb_config.h* file looks just fine for now. You may want to take a look at the *usb_config.h* file to get an idea of what it does for you, so I've included it in the download package at **www.nutsvolts.com**. Likewise, the USB stack's default PIC24FJ256GBxxx *usb_descriptors.c* file can be left alone if you wish. I made a very slight "branding" modification to one of the descriptor strings in the *usb_descriptors.c* file:

```
//Product string descriptor
ROM struct{BYTE bLength;BYTE bDscType;WORD
string[26];}sd002={
sizeof(sd002),USB_DESCRIPTOR_STRING,
{'E','D','T','P','
',P','I','C','2','4','/','P','I','C','3','2','M'
,'X',' ','T','R','A','I','N','E','R'
}};
```

Everything else in the *usb_descriptors.c* file was left untouched. The *usb_descriptors.c* file for this project is geared towards a HID device and uses the default PID and VID assignments. Recall from our previous HID discussions that these devices do not need to have special drivers loaded on the host to operate.

The "branding" we've been doing pays off at the beginning of the *main.c* file:

```
/** CONFIGURATION ******************************/

#if defined(EDTP_PIC24F_PIC32MX_TRAINER)
    _CONFIG1( JTAGEN_OFF & GCP_OFF & GWRP_OFF &
    COE_OFF & FWDTEN_OFF & ICS_PGx2)
    _CONFIG2( 0xF7FF & IESO_OFF & PCKSM_CSDCMD &
    OSCIOFNC_OFF & POSCMOD_HS &
FNOSC_PRIPLL & PLLDIV_DIV2 & IOL1WAY_ON)
#else
    #error No hardware board defined, see
"HardwareProfile.h" and __FILE__
#endif
```

Configuration fuses in _CONFIG1 are set to disable the PIC24FJ256GB106's JTAG interface and any PIC code protection schemes. _CONFIG1 also nixes the watch dog timer and sets the programming/debugging port at pins 17 and 18 of the PIC24FJ256GB106.

_CONFIG2 deals mostly with the oscillator, clocks, and PLL settings. The fuses are set to accommodate the 8 MHz HS primary oscillator configuration that feeds the 4x PLL for the CPU clock and the USB PLL. To provide the 48 MHz USB clock from an 8 MHz input clock, we must specify PLLDIV_DIV2 in the _CONFIG2 fuse configuration string.

The *main.c* file is a very good example to use as a starting point for your own USB application. For the purposes of our discussion, I modified the *main.c* UserInit function to turn off the TPS2041 MOSFET switch until the USB link was totally enumerated and entered the CONFIGURED state:

```
void UserInit(void)
{
    //Initialize all of the LED pins
    mInitAllLEDs();
    DIS_5V();        //disable the TPS2041
output
```

The TPS2041 output is enabled only after the PIC24F/PIC32MX USB Trainer enters the USB CONFIGURED state:

```
        if(USBDeviceState == CONFIGURED_STATE)
        {
          EN_5V();   //enable TPS2041 output
        }
        else
        {
          DIS_5V();   //disable TPS2041 output
        }
```

This is a good time to show you how the LED defintions are used as they follow the TPS2041 output switching code I just revealed to you:

```
        if(USBDeviceState == DETACHED_STATE)
        {
            mLED_Both_Off();
        }
        else if(USBDeviceState ==
        ATTACHED_STATE)
        {
            mLED_Both_On();
        }
        else if(USBDeviceState ==
```

```
POWERED_STATE)
{
    mLED_Only_1_On();
}
else if(USBDeviceState ==
DEFAULT_STATE)
{
    mLED_Only_2_On();
}
else if(USBDeviceState ==
ADDRESS_STATE)
{
    if(led_count == 0)
    {
        mLED_1_Toggle();
        mLED_2_Off();
    }//end if
}
else if(USBDeviceState ==
CONFIGURED_STATE)
{
    if(led_count==0)
    {
        mLED_1_Toggle();
        if(mGetLED_1())
        {
            mLED_2_Off();
        }
        else
        {
            mLED_2_On();
        }
    }//end if
}
```

It's nice to be able to look at the LEDs and determine all of the other enumeration states. However, what you really want to see is LED1 and LED2 alternately blinking on your USB Trainer.

MAGIC SMOKE STATION TEST

Since I'm writing this paragraph, you and I can get up on our donkeys and proclaim success! I've applied power via the USB portal and programmed the PIC24FJ256GB106. If you were here in the shop with me, you would see LED1 and LED2 going to town in an alternating manner and the POWER LED operating without a struggle.

Remember that analog input I mentioned earlier? Well, I can't show you blinking LEDs but since we included the pot macros, I can show you data acquired from the PIC24FJ256GB106's ADC. I'll use the Kadtronix UsbHidDemo application to send the command and receive the data.

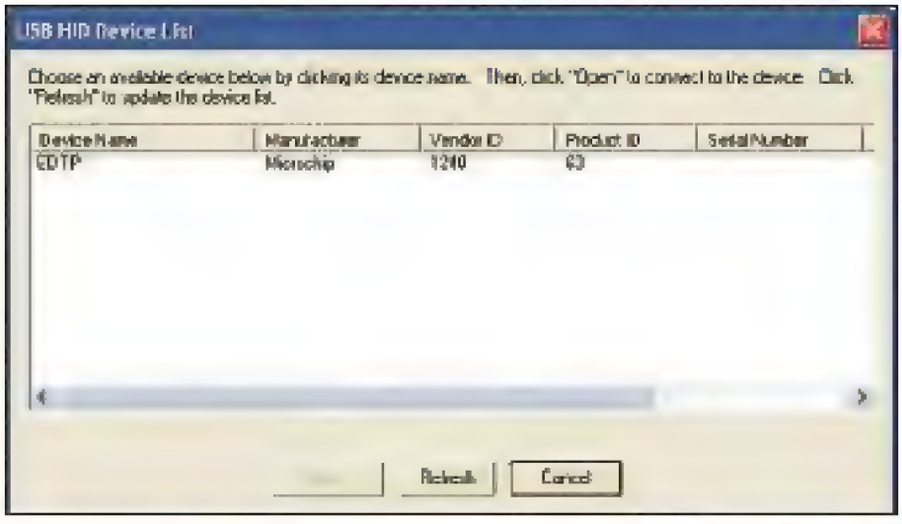
Screenshot 2 confirms that our PIC24F/PIC32MX USB Trainer has been recognized as a HID device by the UsbHidDemo application (which is running on my laptop). The EDTP Device Name was gleaned from the modification we made to the product string descriptor in the *usb_descriptors.c* file. The VID (1240) and PID (63) belong to Microchip and can also be found in the *usb_descriptors.c* file.

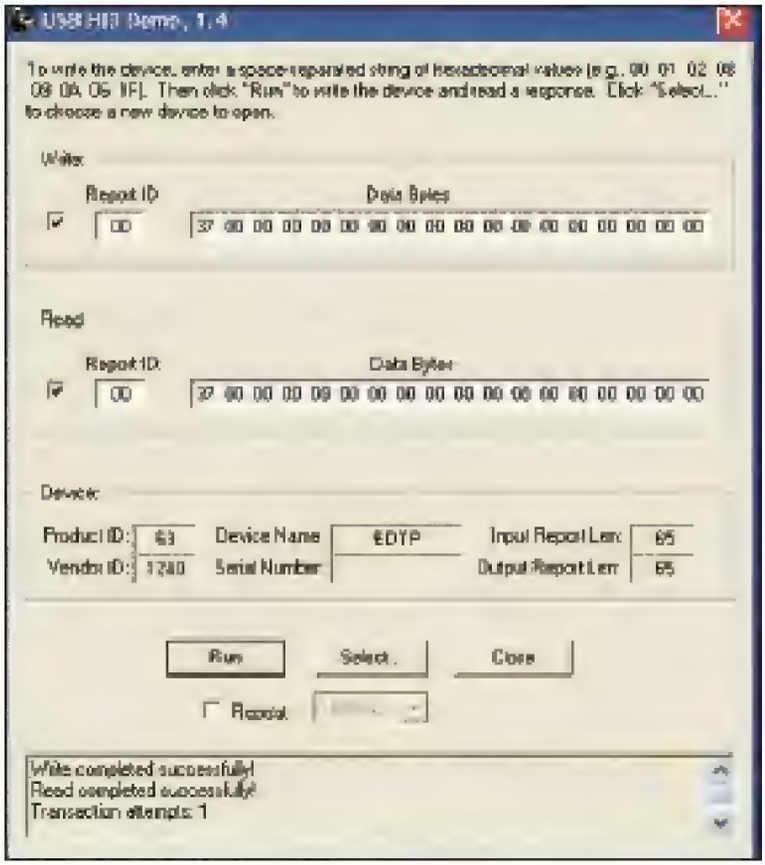
I shorted the PIC24FJ256GB106's AN0 ADC input to ground before issuing the 0x37 command. As you can see in the Read area of **Screenshot 3**, the ADC returned the command value followed by the ADC value of 0x0000. **Screenshot 4** returned the 10-bit value of 0x3FF as I applied +3.3 volts to the ADC input before issuing the command to take a reading from the potentiometer's wiper. The code used to read the potentiometer is relatively simple and is provided for us in the *main.c* demo application:

```
WORD_VAL ReadPOT(void)
{
    WORD_VAL w;


        #if defined(EDTP_PIC24F_PIC32MX_TRAINER)
          AD1CHS = 0x0;          //MUXA uses AN0

        // Get an ADC sample
        AD1CON1bits.SAMP = 1;  //Start sampling
        for(w.Val=0;w.Val<1000;w.Val++);
//Sample delay, conversion start automatically
        AD1CON1bits.SAMP = 0;  //Start sampling
            for(w.Val=0;w.Val<1000;w.Val++);
//Sample delay, conversion start automatically
        while(!AD1CON1bits.DONE);  //Wait for
                                   //conversion
                                   //to complete


        #else
            #error
        #endif

        w.Val = ADC1BUF0;


    return w;
}//end ReadPOT
```

Note that branding comes in handy once again as the ADC commands are particular to the PIC24F/PIC32MX USB Trainer. The ReadPOT function defines the analog port to read and, in this case, it is AN0. The ReadPOT

■ SCREENSHOT 2. The Device Name is taken from the product descriptor string we modified. The VID and PID are also found in the *usb_descriptors.c* file.





■ SCREENSHOT 3. The PIC24FJ256GB106's AN0 input is grounded when I sent the 0x37 command. Note the PIC's ADC converter returned 0x0000.

function is called from the 0x37 case statement that is rolling around in the *main.c* file:

```
    case 0x37: //Read POT command. Uses ADC to
measure an analog voltage on one of the ANxx I/O
pins, and returns the result to the host
    {
        WORD_VAL w;

        if(!HIDTxHandleBusy(USBInHandle))
        {
                mInitPOT();
                w = ReadPOT();//Use ADC to read
the I/O pin voltage.
                ToSendDataBuffer[1] = w.v[0];
//Measured analog voltage LSB
                ToSendDataBuffer[2] = w.v[1];
//Measured analog voltage MSB
                USBInHandle =
HIDTxPacket(HID_EP,(BYTE*)&ToSendDataBuffer[0],64
);
        }
    }
    break;
```

The mInitPOT() macro has its roots in the *TRAINER.h* file. The ReadPot function as well as the 0x37 case code are part of *main.c*.

KEEP UP WITH SERVO MAGAZINE

If you're a *SERVO* reader, you already know that with minimal hardware and firmware modifications you can plug the PIC24F/PIC32MX USB Trainer into the expansion project hardware we assembled over there. Just in case you missed it, the *SERVO* expansion board project added an RS-232 portal, a 2 x 16 LCD, and an XBee-Pro transceiver to the ZeroG - PIC24FJ128GA006 Trainer.

With the exception of the PIC24FJ256GB106's USB capability, the ZeroG Trainer's base hardware is identical to that of the PIC24F/PIC32MX USB Trainer. The ZeroG Trainer and the USB Trainer hardware similarities allow the reuse of code, as well. For instance, the LCD can easily be incorporated into a PIC24F/PIC32MX USB Trainer design as the hardware hookup, and the LCD driver firmware have been proven on the PIC24FJ256GA006.

In the end, the ability to reuse technology in your projects saves time and money. Having 16-bit USB knowledge in your Design Cycle isn't bad either. Be here next time as we'll replace the PIC24F/PIC32MX USB Trainer's PIC24FJ256GB106 with a PIC32MX575F512H. **NV**

SOURCES

EDTP Electronics, Inc.	*Microchip*
PIC24F/PIC32MX USB Trainer	PIC32MX575F512H
ZeroG - PIC24FJ128GA006 Trainer	PIC24FJ256GB106
www.edtp.com	PIC24FJ256GA006
	MPLAB C for PIC24 MCUs
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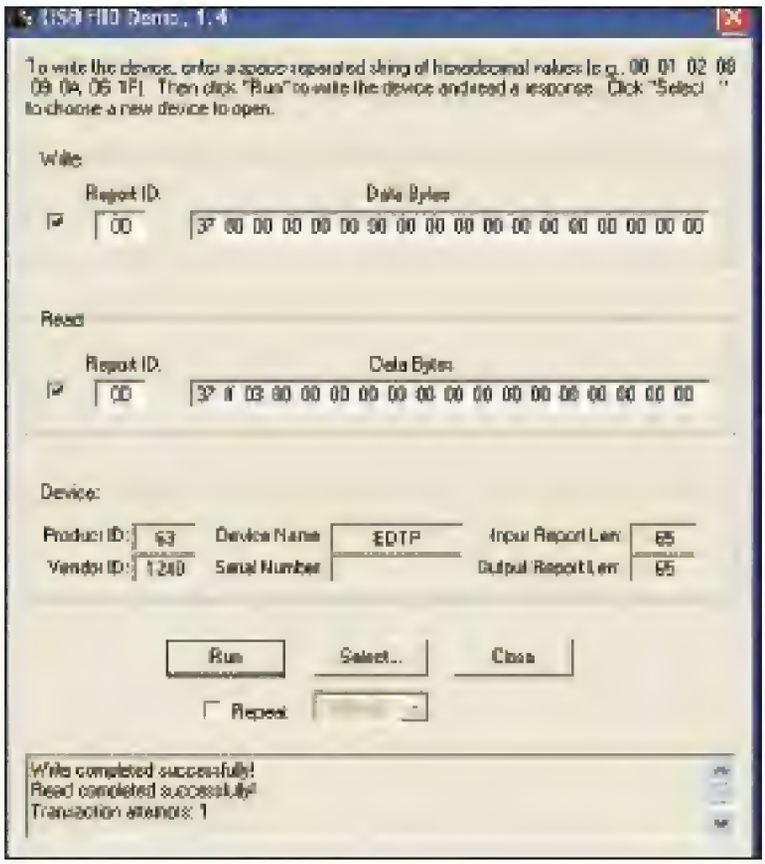
Fred Eady can be contacted via email at fred@edtp.com.

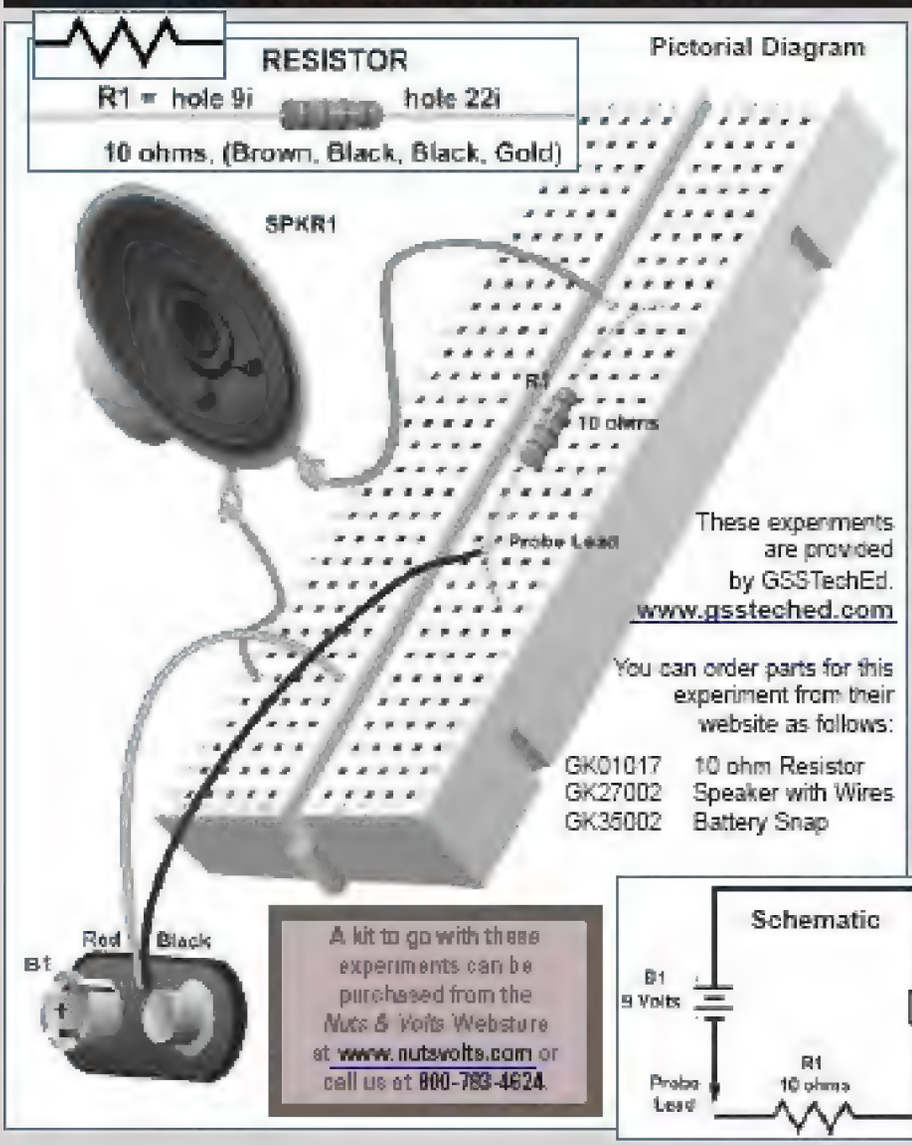


■ SCREENSHOT 4. This shot shows the results of applying +3.3 volts to the PIC24FJ256GB106's AN0 input. Just as expected, its 10-bit ADC returned the maximum reading of 0x03FF.

FUNDAMENTALS FOR THE BEGINNER

HOW A SPEAKER WORKS

A speaker is an electromechanical device. It has a coil, a magnet, and a paper cone. These three parts are mechanically connected in such a way that when current is increasing or decreasing in the coil, the paper cone moves which causes sound. So, the function of a speaker is to convert electrical energy into sound.

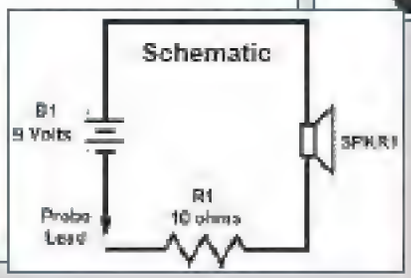


These experiments are provided by GSSTechEd. www.gsstecheed.com

You can order parts for this experiment from their website as follows:

GK01017	10 ohm Resistor
GK27002	Speaker with Wires
GK35002	Battery Snap

A kit to go with these experiments can be purchased from the *Nuts & Volts* Webstore at www.nutsvolts.com or call us at 800-783-4624.



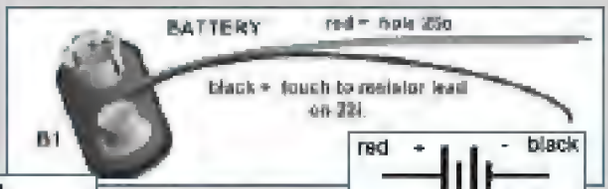
1. Build the Circuit.

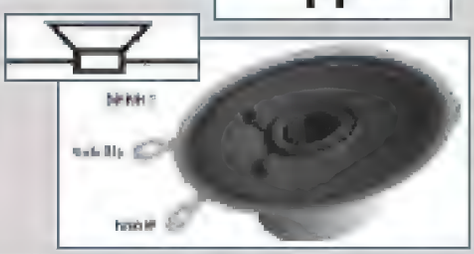
Using the schematic along with the pictorial diagram, place the components on a solderless breadboard as shown. Verify that your wiring is correct.

2. Do the Experiment.

Theory: In this circuit, the electrons flow from the battery through the resistor, through the speaker, and back to the battery. To make sound, the coil requires a constant change in current. The speaker will only emit sound when you first touch the wire to the resistor, and when you disconnect the wire from the resistor.

Procedure: Connect a nine-volt battery to the battery snap and tap the probe lead to the 10 ohm resistor. (Do not leave the wire touching the 10 ohm resistor or it will burn out the battery and ruin the speaker.) Reverse the battery leads and do the procedure again. Observe how the cone moves in the opposite direction.





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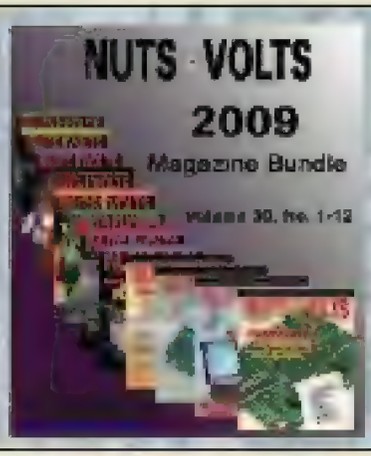

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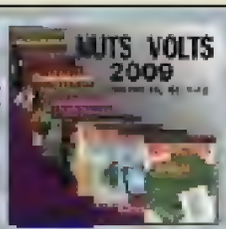

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C PROGRAMMING - HARDWARE - PROJECTS

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AVR Memory Part 1: Introduction

by Joe Pardue

Recap

Last month, we put an ATmega644 on a breadboard and I promised that this month we'd transfer the design to a PCB so that we would have an easy-to-use open-source hardware platform to learn with. Unfortunately, I messed up. I had it all working and even tested the PCB with my bootloader. Then it quit working. As the deadline for this article began to stand up and glare at me with tendrils of smoke and occasional puffs of fire directed my way, I did what any sensible person does. I panicked and messed things up even worse. Am I mortified? You betcha! So, the PCB will be delayed and this month we will begin a mini-series on AVR memory architecture with the goal of understanding each type, providing examples on how to use each, and in the final episode we will use what we've learned to write a bootloader in C. Somewhere along the line I should get the BeAVR PCB and associated software working again, and we'll see it then.

Computer Memory

Whether it is a bank of switches, a strip of cardboard with holes punched in it, or a microscopic slab of very pure sand with metals etched onto it — computers require memory for programs and data.

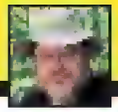
Computer memory has two distinct aspects. First, there is the physical medium that holds the data — usually a configuration of transistors that can be set to hold a voltage representing single-bit values of either 1 or 0. The circuits are grouped in bytes (eight bits) or other sized groups that are dealt with as a unit. Groups of these physical data storage units are arrayed so that they can be accessed individually by their addresses. Addresses are the second distinct aspect of computer memory and are independent of the physical method used to store the data.

We thus think of memory as being a sequence of physical locations to store data of a certain size (eight bits for AVRs) that each have a unique address that we use to read or write data from that specific location. Let's do a thought experiment to help understand this. If we have a 2K memory, we have 2048 physical locations to store data. [Traditionally, we use 'K' to denote 1024 in computers since the number system is binary and 2^10 is 1024. In decimal systems, we use the lower case 'k' for 1000. Since there are no real standards for this, it can get confusing.] Each of these 2048 locations has an address from 0 to 2047 — but since we like to express these numbers in hexadecimal, they would number from 0x0000 to 0x07FF.

Figure 1 illustrates the separation of the address concept from the real (physical) location where data is stored. The first thing we can see about the difference between the stored data and the address of the stored data is that the stored data is eight bits meaning that it can encode 256 unique values — 0 to 255 — but the total number of these eight bit locations is a much larger number: 2048. So, we require more bits to uniquely encode the addresses of those locations. An 11-bit number could encode 2048 values, but with small microcontrollers like the AVR we typically deal with only two sizes of numbers in hardware: either eight-bit **bytes** or 16-bit **words**. So, logically we would use the larger words to encode

■ FIGURE 1. Hello World! in memory.

Address	Data
. . .	. . .
0x0400	0x48
0x0401	0x65
0x0402	0x6C
0x0403	0x6C
0x0404	0x6F
0x0405	0x20
0x0406	0x57
0x0407	0x6F
0x0408	0x72
0x0409	0x6C
0x040A	0x64
0x040B	0x21
0x040C	0x00
. . .	. . .
0x0678	0x04
0x0679	0x00



addresses. We express bytes as two digit hex numbers (0x00 to 0xFF) and words as four digit hex numbers (0x0000 to 0xFFFF) [where the leading 0x just means that it is a hex number]. It then follows that in **Figure 1**, the addresses are words and the data are bytes. We use '...' to indicate that there are addresses and data before and after what is shown.

In this specific case, we see addresses 0x0400 to 0x040C (decimal 1024 to 1036) and we see a random appearing sequence of data for each address beginning with 0x48 and ending with 0x00. Then, we see '...' to show us that further along at the addresses 0x0678 and 0x0679 we have the data value 0x04 and 0x00. We assume that there is lots of other data at the other addresses, but since we aren't showing them they aren't needed for this explanation. The first sequence of bytes aren't as random as they appear. They are the ASCII codes [link: **www.asciitable.com**] for the characters 'Hello World!' followed by the null byte 0x00 that to C indicates the end of a string.

What Do You Call Eight bits?

Originally, C had data types with names like **char** or **int** and the size of these data types was machine dependent. K&R (*The C Programming Language*, Brian Kernighan and Dennis Ritchie, 2nd edition) defines char: *'a single byte, capable of holding one character from the local character set.'* Since that character set is ASCII, you only need seven bits to encode it. The extra bit is used as a sign bit leading to the bizarre concept (IMHO) of signed and unsigned char. A signed character has values of –128 to 127, and an unsigned character has a value of 0 to 255. There are no negative ASCII characters nor are there any above 127 (in the basic set). The sign lets you use chars as ordinary numbers within the ranges shown above but confuses novices who ask: "Is char a number or a character?"

C has grown a bit since K&R and the C99 standards library defined terms that help make data type more specific and portable by giving them known numbers of bits for a given type. This convention uses the data types int8_t and uint8_t for the unsigned and signed eight-bit types (formerly char), and int16_t and uint16_t for 16-bit data types (formerly int). That's a lot clearer, isn't it? Well, not to me, but after we get past this introductory article, we will stop using the original K&R C names and start using those from C99.

A Few Pointers

Suppose you have the task of writing a function that sends strings of characters out the serial port. There would be many ways to do this, but one way would be to provide that function the address of the first character in a string. Then, the function could send out that character, add one to the address, and send each subsequent character until it runs into the character that C considers to end a string: nul (0x00) that we mentioned above. Such a function operating on the data in **Figure 1** would send 'Hello World!' on the serial port. A function like this would need some way to get the address of the string. In C, we can send that address in the function parameter list by using a pointer. In C, we use '*' to indicate that a variable is a pointer. We'll see this again shortly.

Please don't glaze over here, you are going to have to understand this to move on with C programming and the next concept is the one that trips up most folks just starting out with C. The final two addresses shown in **Figure 1** (0x0678 and 0x0679) are for the values 0x04 and 0x00. You could read these two bytes and combine them into the word 0x0400 and use that as the address of some other location in the memory which — by no accident — is the address of the first item in the data sequence for the 'Hello World!' string that begins at address 0x0400. **This is a key concept in programming**: data values can be the address of other data values. When data values are used as addresses of other data, they are called **pointers**. In our example, the data at addresses 0x678 and 0x679 are used as a pointer to the 'Hello World!' string that begins at 0x0400. I admit that this discussion has been repetitious, but for some folks, pointers are the single most difficult concept to get past in all of computer programming.

Pointers Can Be Dangerous

Pointers are the reason that many refer to C as a mid-level rather than a high level programming language. In high level languages, the programmer only deals with data and the compiler makes all the decisions about the addresses. In low level languages (like assemblers), the programmer assigns the addresses to the data. In C, we are not required to play with addresses, but are allowed to if we want to. Some things can only be done using pointers. Pointers also allow us to do many things more efficiently and cleverly than would otherwise be the case. But they can be dangerous. To quote K&R, p 93: *"Pointers have been lumped with the goto statement as a marvelous way to create impossible to understand programs. This is certainly true when they are used carelessly, and it is easy to create pointers that point somewhere unexpected. With discipline, however, pointers can also be used to achieve clarity and simplicity."* This would be a good time to assert that if you really want to learn the C programming language, you should get K&R. Books like my *C Programming for Microcontrollers* (available from *Nuts & Volts*) are also good for getting started specifically with micros, but to really get the religion, you need a copy of the "bible" and K&R is it.

As an example of a dangerous misuse of pointers, I once used a pointer to sequentially access the video buffer of an IBM PC. I made a simple 'fence-post' error,

that is, I started a count with 1 instead of 0, and wrote the last data byte to an address that was one location outside of the video buffer. That byte was only occasionally important enough to crash the system and I nearly went nuts trying to figure out what was wrong. When your device crashes intermittently with no apparent rhyme or reason, you may well be suffering from a bad pointer use.

Declaring Pointers

We declare a variable to be a pointer by preceding its name with an *, called the *indirection* or *dereferencing* operator:

```
char *q; // q is a pointer to a char
```

We get the address of a variable using &, called the address of operator:

```
// create a character variable initialized
// to 0x48
char v = 'H';

// put the address of v in the pointer q
q = &v;
```

In the case of the AVR, the compiler will know to create a 16-bit storage location for the '*q' variable just like it knows to create an eight-bit location for the 'v' variable. Now, take a deep breath and commit all that to your memory so that the next time you see something like *myOhmy, you'll know that it is the address of something — a pointer — and if you see &myAmi you'll know that this is an operation that yields the address of the variable myAmi. Then, the statement myOhmy = &myAmi will make perfect sense.

C Programming Examples

To help our understanding, let's play with these concepts on a PC using a simple and free C compiler. We'll switch over to AVRs next month. Let's use Pelles C that you can download from **www.smorgasbordet.com/pellesc/**.

The Canonic First Program

This is canonic since it comes from the C bible (K&R p. 6).

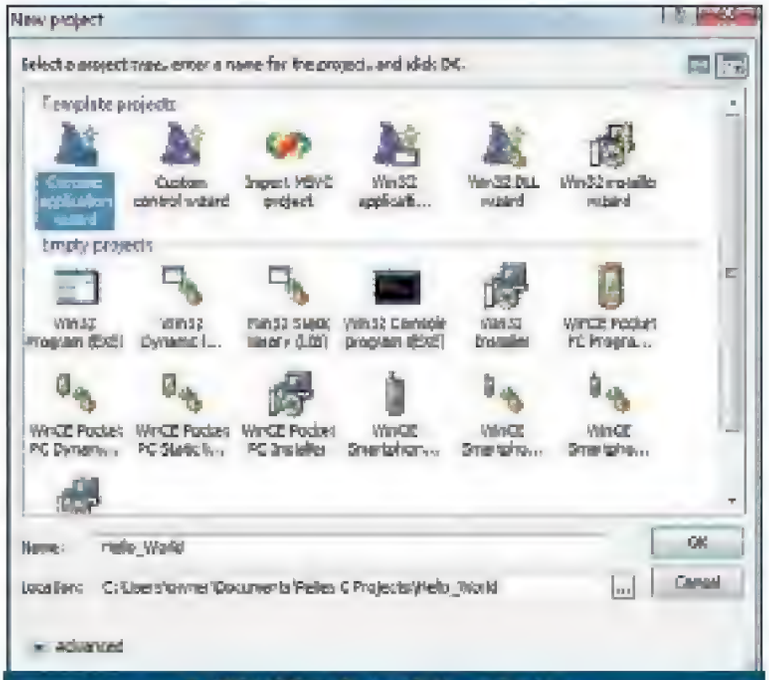


FIGURE 2. Pelles C New Project.

```
#include <stdio.h>

main()
{
        printf("hello, world\n");
}
```

Interestingly, the Pelles C has a wizard application that creates a version of this program as a template for writing other programs.

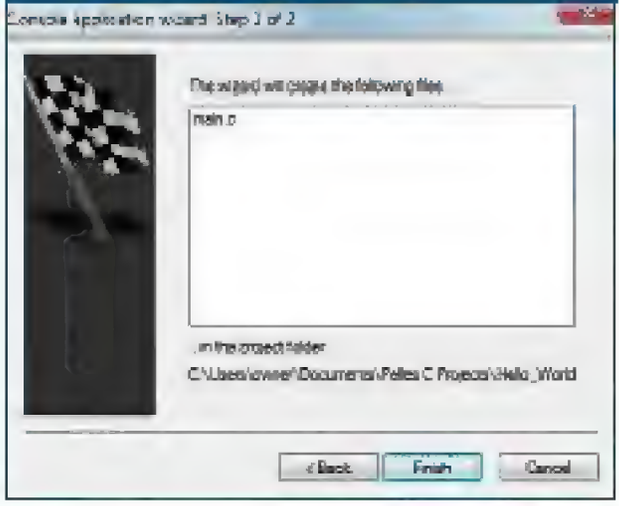
Open Pelles C, click on the File menu, and select New\Project. **Figure 2** shows the resulting window with 'Console Application Wizard' highlighted and Hello_World typed into the 'Name:' field.

Click OK and you'll see the window shown in **Figure 3**. Check the 'A "Hello, world" program. Yes, the Hello World program is so basic that it is included for you!

Click Next and you'll see the window in **Figure 4**. Now click the finish button. As if by magic, Pelles will

FIGURE 3. Pelles C Console Wizard Part 1.

FIGURE 4. Console Wizard Part 2.



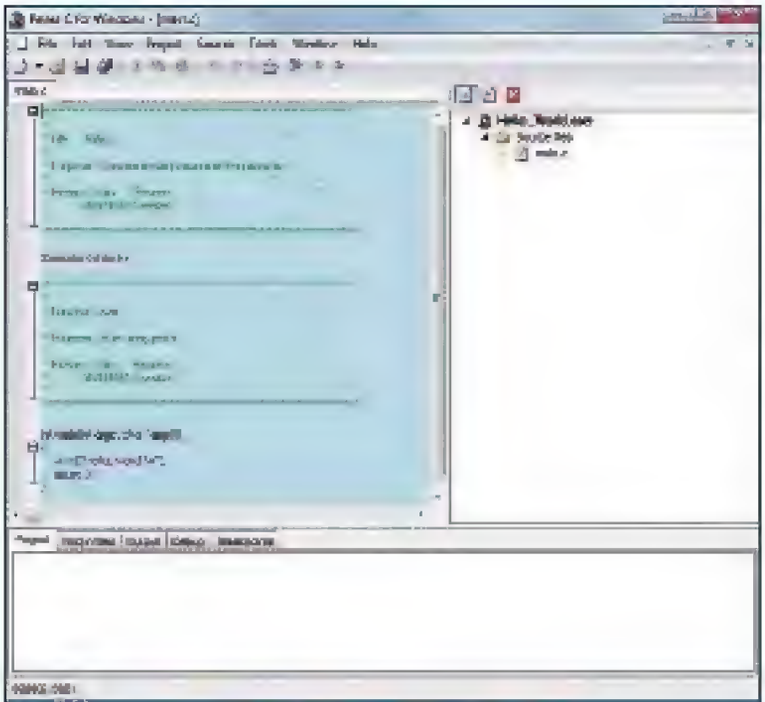


FIGURE 5. Pelles C Hello World!.

write your first Hello World program for you as shown in **Figure 5**. Next click the 'Compile' button, the 'Execute' button, and you'll see the console output shown in **Figure 6**.

Whoa! That's so easy that it almost makes us forget that there are some not so easy things going on under the hood, and our job is to learn about those not so easy things. So, for the time being we will forget about the easy way to say hello and revert to some more basic C functions that are closer to the discussion about memory and pointers.

'Hello, World!' The Hard Way

Using an Array

In C, when we want to create a sequence of characters in memory like we saw in **Figure 1**, we have several options. However, the one most closely related to the memory discussion is to define an **array** (a continuous sequence of memory locations) and initialize it with the data we want stored sequentially in memory. Pelles C allows us to revert to the original C data types: char for eight-bit and int for 16-bit (let's not quibble at this point about signed and unsigned okay?). So, we create our data sequence by using:

FIGURE 6. Console Hello World!.

```
char greet[] = "Hello, World!\n\0";
```

This tells the compiler to store the indicated characters as a sequence in memory. The '\n' and '\0' are special non-printable characters; the first is newline (an instruction to the output device to create a new line) and the second is nul, with a value of 0. We added the '\n' (which isn't in **Figure 1**) to separate the output line in the console display. The following program will output the data to our terminal:

```
#include <stdio.h>

int main(int argc, char *argv[])
{

        int i;
        char greet[] = "Hello, World!\n\0";

        for(i =0 ; greet[i] != '\0'; i++)
        {
                putchar(greet[i]);
        }

       return 0;
}
```

This program uses the putchar() function from the stdio library and reads each character from the memory one at a time, and outputs each character individually. In the first program, we used the printf() function, but under the hood the printf() function calls some code not unlike what we see here. The 'for' loop sends a character from the greet[] array, increments the address of the array, then if the value isn't equal (!=) to '\0' it sends the character. It loops through each address until it finds the '\0' character, then it stops.

Using a Pointer

Now suppose we have a bunch of arrays of data and we want to simplify our lives by writing a function whose job it is to send out a nul-terminated array (a string) to the console. We could write a function, consoleOut() and use it as follows:

```
#include <stdio.h>

void consoleOut(char *); //declare the function

int main(int argc, char *argv[])
{

        char greet[] = "Hello, World!\n\0";
        char south[] = "Howdy, ya'll!\n\0";
        char north[] = "Get oudda my face!\n\0";

        consoleOut(greet);
        consoleOut(south);
        consoleOut(north);

         return 0;
}

void consoleOut(char *x)
{
        int i;
```

```
        for(i =0 ; *x != '\0'; i++)
        {
                putchar(*x);
                x++;
        }
}
```

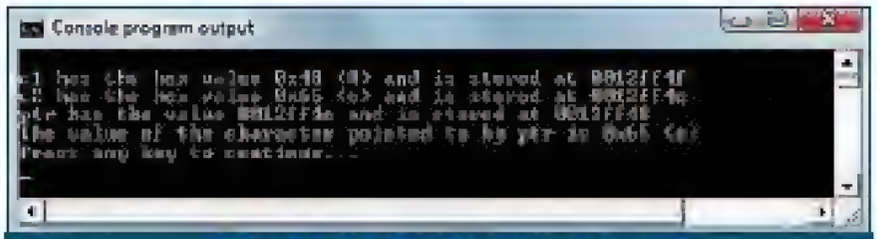


FIGURE 7. Console pointer demo.

In C, the name of an array without the following square brackets is a pointer to the first element in the array data sequence. For instance, if the C compiler just happened to follow our example and put the characters in the greet[] array beginning at address 0x0400 as shown in **Figure 1**, then the word 'greet' will be a pointer to address 0x0400. (Our compiler might, theoretically, store that address at addresses 0x0678 and 0x0679 also as shown in **Figure 1**.) So, we define the consoleOut(char *) to tell the compiler that this function takes a pointer to a character as a parameter (char *). Then, when we use consoleOut(greet) the compiler knows that 'greet' is a pointer to a char and to use the address of the array named 'greet' (hypothetically 0x0400) and not any element of that array. We send the specific 'greet' pointer in the parameter list, but the function is generic so it receives the pointer as '*x' and uses it as a pointer to the data in the greet array. So, when the 'for' loop begins, *x is pointing to 'H', then we increment the pointer. Notice that when we increment the address we are using 'x' which the compiler knows is the address, so x++ adds one to the address.

Here's one more example to show a use of the 'address-of' operator &.

```
#include <stdio.h>

int main(int argc, char
*argv[])
{
  char c1 = 'H';
  char c2 = 'e';

  // Assign the address of c2
  // to ptr
  char *ptr = &c2;

  printf("\n");
  printf("c1 has the hex value
  0x%X (%c) and is stored at
  %p\n"\
                ,c1, c1,(void
                *)&c1);
  printf("c2 has the hex value
  0x%X (%c) and is stored at
  %p\n"\
                , c2, c2,(void
                *)&c2);
  printf("ptr has the value %p
  and is stored at %p\n"\
                , ptr, (void
        *)&ptr);
  printf("The value of the
  char pointed to by ptr is
  0x%X (%c)\n"\
                , *ptr,*ptr);

        return 0;
}
```

Note that the '\' at the end of the line allows the printf() statements to continue on the next line which is only necessary here to reduce the width of the source code to make it fit the text. Also, don't worry so much about all the 'stuff' like 0x%X in the printf() statements which are out of the scope for this discussion. Just pay attention to the use of '*' and '&'. Executing this code yields the results shown in **Figure 7**.

Next month, we will apply some of this hard-won knowledge to the AVR and give examples that run on microcontrollers. Meanwhile, if you want to get a leg up on C, buy the book *C Programming for Microcontrollers* from *Nuts & Volts*, and if you want to get two legs up, get the combo with the book and hardware projects kit. It will come in handy. **NV**

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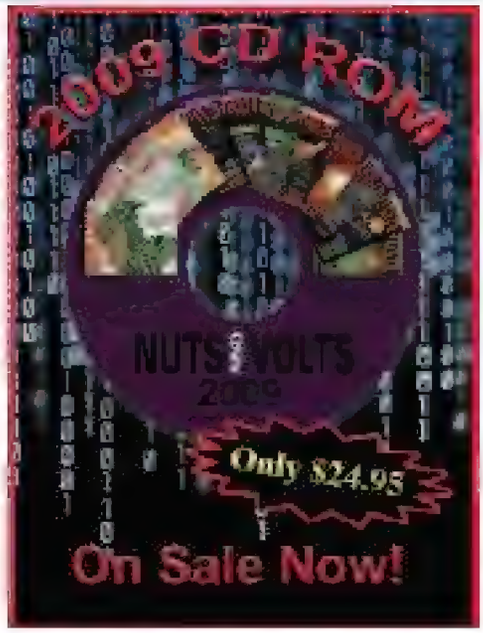

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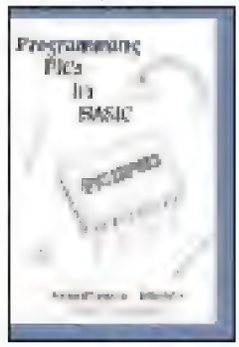

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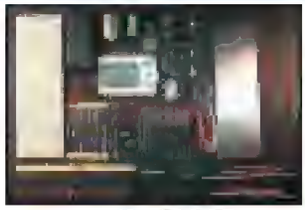

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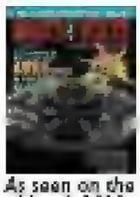

As seen on the March 2010 cover

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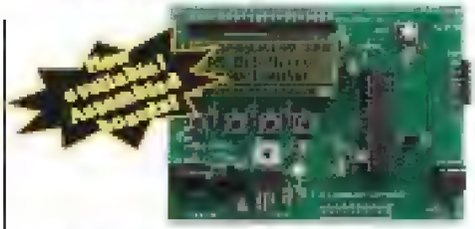

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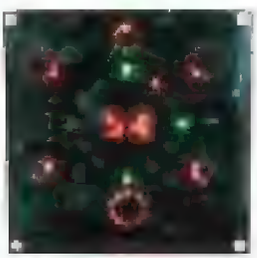

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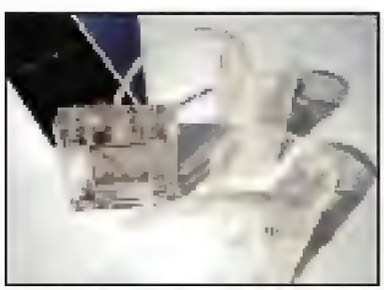

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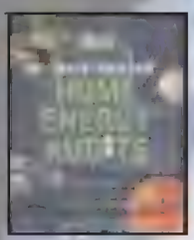

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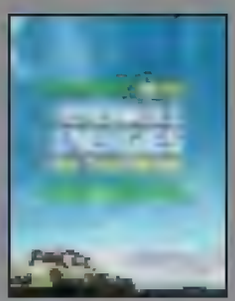

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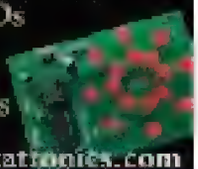

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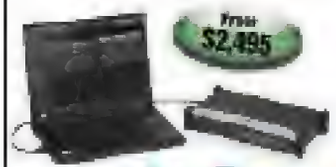

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Also keying off a very popular Skooba product design, the new SkoobaWraps are simple, "portable padding" that can be wrapped and self-secured around virtually any suitable object, from a compact camera in the small wrap, to a compact laptop in the large one. Much like the Cable Stable, the Wraps are an ideal way to cope with the challenges of air travel. They can be used to instantly protect and pack just about anything, from handheld video games to netbooks, iPads and e-readers, to travel souvenirs.

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#6101 **Timothy Edwards**
San Diego, CA

AC Motor Control

I'm building an alt-az antenna rotor controller from scratch, but I'm having trouble with the circuit for controlling the AC motor in the RadioShack rotator. I've tried using a TRIAC with little success. I believe they are my answer but I don't understand how to use them. What I need is a circuit that will accept one direction bit and one enable bit that will control a motor's direction of spin. The original controller acheived this by feeding one or the other non-neutral leads of the motor with ~22V AC; the third lead is common neutral.

#6102 **Matt Williamson**
Houston, BC

Quartz Cookoo Clock

My quartz cookoo clock has a photodiode to turn off the clock at night, but I want it to work at night. Can I just remove the photodiode?

#6103 **Doug Cardona**
Rincon, Puerto Rico

Driveway Sensor

I want to set up a home driveway sensor similar to a traffic light actuator, by using a single wire loop in the pavement that senses vehicles by changing the frequency of an oscillator. I need to know how it works and how to build it.

#6104 **W. Rogers**
via email

Vacuum Cleaner Soft Start

I have a Hoover EmPower vacuum cleaner that causes the breakers in my home to trip almost every time I first power it on. After a few minutes of use, I can turn the machine off and back on with no problem. I am thinking that the initial inrush current is too much for the breakers (they are GFCI protected). Does anyone know of some sort of soft start circuit or any other trick that may help?

#6105 **Jonah G.**
Nashville, TN

Remote Start

I am buying my wife a car, but she will not get the garage. So, I agreed to buy her a remote start. I have looked around for one with a clock that will start the car every weekday. So far, no luck. I'm thinking one could program a PIC to start the car like at 8:30 am for 15 minutes, except Saturday and Sunday. Of course, with an override switch for vacations. Any ideas?

#6106 **Michael McKenna**
Milwaukee, WI

RS-232 To Audio and Back

I have puppets which I can control with a servo controller board attached to the serial port of the computer. I want to record the serial out to audio, burn a CD, and then play the audio from the CD and send the output to the servo controller board, as though it were coming from the serial port of the computer. Anyone have an idea or could help design a hardware solution to this need?

#6107 **George Wood**
Lakeside, CA

Noise Suppression in PIC Projects

We develop products with PIC tech, but are unable to beat the noise. Can anybody suggest a solution?

#6108 **Suresh Naidu**
India

PIC16F876A

What is the least expensive system to use to program a PIC16F876A? I got one as a sample from Microchip; now I don't know what to use to talk to it.

#6109 **Joseph Walker**
Newville, AL

>>> ANSWERS

[#2101 - February 2010] Motion Sensing Faucet

I want to create a motion sensing electronic flow faucet. The solenoid valve is normally closed with an operating voltage of 24V.

I'm new to this hobby, so I'm not sure where to start as far as the circuit design goes. I thought of purchasing an electronic light switch and modifying it to trip the solenoid valve, but the switches are expensive.

#1 Harbor Freight Tools (www.harborfreight.com) has an inexpensive ($10) proximity detector nightlight (part number 95276-1AFH) which can be modified. Remove the LED light

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and replace it with a solid-state relay that has sufficient capacity to operate the 24 volt solenoid. The water will shut off within 10 to 15 seconds after you leave. The nightlight has a sensor to shut it off in the daytime. You will want to cover that with some black tape.

Russell Kincaid
Milford, NH

#2 You can try a PIR sensor from www.parallax.com. Turn on a small five volt relay which, in turn, would turn on the 24 volt solenoid.

You might want to use a 2N3904 transistor or 2N7000 MOSFET between the PIR sensor and 5V relay.

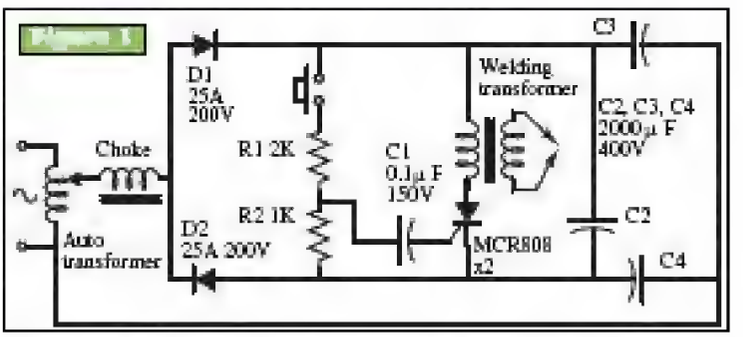
Henry H.
via email

[#2102 - February 2010] Spot Welder

Where can I find or make a simple spot welder suitable for rebuilding battery packs?

#1 There are two types of spot welders: (1) capacitive discharge; and (2) timed AC, as illustrated in references [1] and [2], respectively. A charged capacitor is discharged into a step-down spot welding transformer in type 1. A high current pulse is applied to the welding probes. In type 2, a timed burst of AC is applied to the primary of the welding transformer. The secondary of a few turns of heavy wire applies a few hundred amps to the welding probes.

Figure 1 shows the circuit of a capacitive discharge spot welder in reference [1]. A variac adjusts the line voltage applied to voltage doubler D1, D2, C2, C3, and C4. The MCR808 is two parallel 18A 100V SCRs. It seems like it should be 400V SCRs. The push switch triggers the SCR gate, discharging C2 into the primary of the welding transformer when the anode-cathode conducts. The low voltage secondary of the transformer applies a pulse of high current to anything between the welding electrodes. No information was provided for the choke. However, I recommend something in the neighborhood of 20 mH @15A to 40 mH @ 7.5A. The stated mH rating will limit the AC input current to the @current rating. Reference [2] provides information on a welding transformer. Since high mH, high current chokes are a custom built item these days, consider replacing the choke with a 100 ohm 100 watt resistor to limit charging current and short circuit current.



Reference [1] also shows a timed AC spot welder consisting of a discrete component timer and high current anti-parallel SCRs switching the AC. That somewhat dated circuit is not shown here. For a modern AC spot welder, see reference [2]. It uses a solid-state relay to switch AC to the primary of a 700VA welding transformer. The solid-state relay is enabled by an O/S (one-shot) timer for the duration of the weld. Reference [1] recommends an interval of 20 milliseconds to one second. As the O/S times out, a burst of high current AC from the welding transformer secondary is applied to the probe circuit.

References:

[1] "Controlled Rectifier Welding Controls," Circuits Manual," Motorola Semiconductor, 1964.

[2] "The Home-Brew Spot Welder," www.stumbleupon.com/su/31rXWC/www.5bears.com/welder.htm.

Dennis Crunkilton
Abilene, TX

#2 Powerstream at www.powerstream.com has spot welders and supplies particularly for NiCd, Li-ion, NiMH, and similar battery packs.

Walter Heissenberger
Hancock, NH

[#2103 - February 2010] Centrally Monitor Door Status

I want to monitor the open or close status of 20 or more doors in a building. Are there devices made that would send a location address and magnetic door switch status via Cat 5 cable about 200' back to a central panel?

I would like these devices to share a common pair and be powered from the central panel too. The panel would light up an LED.

#1 Although it's a lot of fun for readers of this magazine to design a circuit to fulfill a need (and I'm one of them), I thought that a search of a possible existing product might be more cost effective. I came across an interesting product manufactured by DCS. Model AMP-700 is a compact (1.1" x 3.4" x 0.75") addressable door/window sensor with a built-in reed switch. You can chain as many as 32 of these devices together with just two wires. These sensors are available online for around $15 apiece.

They must be used with a compatible DCS control panel (e.g., Power832). For display, they have a model PC5532 LED keypad with 32 individual LEDs to indicate which sensor is active. Check their website at www.dcs.com for more info and search the Internet for suppliers.

Bob Kovacs
Barnegat, NJ

#2 I contacted a friend in the security business and he tells me that there is an alarm panel made by

Bosch. They have what are called popits that are a single zone unit with addressing. These use a four conductor daisy chain wire. You can add up to a couple hundred of them to one line. But, this looked like a good project to me, so I came up with a design and built a simple setup. To have the doors share a bus, you need intelligence at every door.

Microcontrollers (µC) are so cheap these days, all I believe you need are two chips' worth at each door. A simple µC such as the PIC 12F509 (less than $1) could do all the work at each door in conjunction with a bus interface chip based on RS-485 (e.g., LTC485 at $1.75).

No other interface chips are needed. Using Cat 5 cable (additional design work should be done to look at resistance for the power transmission and max distance), make one pair for the RS485 bus, and use the three other pairs for the 5V power from the central site (triple up the wires for less resistance). The max distance also determines max transmission speed.

RS-485 allows 32 transceivers (doors) on the bus.

A central µC would do poll and response of each door and then output the status to a set of latches wired to the LED panel.

I built a two unit system in my lab, wrote the code to cycle through the addresses and included a simple error checksum (only as far as proving the concept), and it works fine. Two bytes are sent with the address of the door (the poll) and a checksum. Door returns its address, checksum, and status. So if you want to DIY, there's an idea.

Pete Lunt
Fairfax, VA

[#2104 - February 2010] AC Motor Control

I would like a diagram for a three-phase AC motor control that I can build myself. I can find all kinds for DC, but not AC. Could someone point me in the right direction?

#1 Microchip has several evaluation boards for this purpose using their microcontrollers and DSP chips. Look for the MC1.

Walter Heissenberger
Hancock, NH

#2 There is a lot of info at www.irf.com. They have some PDF files for simple motor controls and they also have intelligent power modules that do most of the work. They all need a microcontroller, though, to generate the drive signals.

Powerex is a good source too.

Henry H.
via email

[#2105 - February 2010] Welder Conversion

I want to enhance my Lincoln 225 amp 220 volt AC welder with a circuit that can change the 60 Hz AC to a variable higher frequency. Welding aluminum with a tungsten torch (TIG) requires a variable frequency higher than the 60 Hz to make the best weld due to the nature of aluminum oxide and alloy. It is suggested in my reading that commercial TIG welder circuits change the sine wave to a square wave.

My concept is to add an auxiliary box to house the power supply for the electronics, the cooling fan, and either the cable to a foot switch or rheostat mounted to the torch head or surface mounting. A selector switch will turn the TIG feature on or off to continue to use the original welding feature or to TIG weld.

I have found circuits where the frequency can be varied, but at low voltage and amperage. One article on converting an AC to DC MIG welder suggested the diodes in the rectifier have a peak invert voltage of 1,000 volts for the momentary time when striking the arc, and be able to handle the amperage of the original welder — 225 amps.

#1 The simple answer is that there is no simple answer! Sorry, but the methods of achieving what you have and what you want are quite different. You have (I believe) a basic transformer welder, operating at 60 Hz, with output power selectable by secondary tapping points. What you desire is a high(er) frequency welder output with effectively the same power. Unfortunately, you cannot supply your existing welder with anything much different from 60 Hz, or you will probably destroy the transformer. It just wasn't designed to work at higher frequencies.

So, how can it be done? High frequency welders are effectively switched mode supplies with very beefy output stages and close control of the voltage to accommodate the varing load imposed on them. That's where the conversion of sine wave (mains) to square wave (chopped output) comes from. Since it is a welder, there's no smoothing to speak of. As you can see, this shares next to nothing physically with your original welder.

The appellation of 'MIG' really only specifically implies that it can supply a wire feed through the torch which also supplies the shrouding bubble of inert gas. It doesn't necessarily mean it is high frequency.

The conversion of a welder from AC to DC in your last paragraph, appears to refer to a bolt-on (literally!) half or full wave rectifier. That device has to be able to withstand the inrush current as the arc is struck (before the reactance of the transformer limits the current), and withstand the inductive voltage spike as the arc is broken. So, with a factor of safety applied, yes it has to be that big!

Sally Jelfs
Brackley, England (UK)

#2 You can weld aluminum with your welder as-is. The high frequency is there to strike an arc; this keeps the work from getting contaminated from the electrode. You can scratch-start and weld without high frequency. The AC setting on your welder will stir up the weld puddle and make the impurities come to the top. You can get a high frequency add-on box for your welder and be able to start an arc easier. Reference: *The Procedures Handbook of Arc Welding*, Lincoln Electric.

Frank
via email

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PolarisUSA Video, Inc. 13
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Cunard Associates 27

BUYING ELECTRONIC SURPLUS

Jaycar Electronics 36
WeirdStuff Warehouse 27

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Circuit Specialists, Inc. 82-83
PolarisUSA Video, Inc. 13
Ramsey Electronics, Inc. 18-19

CIRCUIT BOARDS

AP Circuits 45
Cunard Associates 27
Dimension Engineering 37
ExpressPCB 56
Futurlec 44
General Circuits / PCB Cart 13
PCB Pool 36
V-Module 26

COMPONENTS

Cana Kit Corp. 71
Front Panel Express LLC 13
Fun Gizmos 27
Futurlec 44
Jameco 57
Linx Technologies 45
Mouser Electronics 9
SparkFun Electronics 4
V-Module 26

COMPUTER

Hardware

ActiveWire, Inc. 27
WeirdStuff Warehouse 27

Microcontrollers / I/O Boards

Abacom Technologies 38
Fun Gizmos 27
HobbyLab 27
I/O Bridge 44
microEngineering Labs 65
Mouser Electronics 9
Net Media 2
Parallax, Inc. ..... Back Cover
Pololu Robotics & Electronics 39
Solarbotics/HVW 25
Technological Arts 27
Trace Systems, Inc. 55
XGameStation 27

DESIGN/ ENGINEERING/ REPAIR SERVICES

Cana Kit Corp. 71
ExpressPCB 56
Front Panel Express LLC 13
General Circuits / PCB Cart 13
PCB Pool 36
Trace Systems, Inc. 55

EDUCATION

BaneBots 55
Command Productions 26
I/O Bridge 44
LearnOnLine, Inc. 37
NKC Electronics 27
Technological Arts 27
XGameStation 27

EMBEDDED TOOLS

Mouser Electronics 9
NetBurner 7

ENCLOSURES

Front Panel Express LLC 13
Integrated Ideas & Tech. 44

KITS & PLANS

Cana Kit Corp. 71
DesignNotes.com, Inc. 27
Jaycar Electronics 36
NetBurner 7
NKC Electronics 27
QKITS 27
Ramsey Electronics, Inc. 18-19
Solarbotics/HVW 25
XGameStation 27

MISC./SURPLUS

All Electronics Corp. 3
Front Panel Express LLC 13
WeirdStuff Warehouse 27

MOTORS

BaneBots 55
Jameco 57

PROGRAMMERS

Futurlec 44
microEngineering Labs 65

PROTOTYPING

PrintAProto 27

PUBLICATIONS

Lakeview Research 27

RF TRANSMITTERS/ RECEIVERS

Abacom Technologies 38
Linx Technologies 45

ROBOTICS

BaneBots 55
Fun Gizmos 27
HobbyLab 27
Jameco 57
Lemos International Co., Inc. 26
Lynxmotion, Inc. 45
Net Media 2
Pololu Robotics & Electronics 39
Solarbotics/HVW 25
SparkFun Electronics 4

SATELLITE

Lemos International Co., Inc. 26

SECURITY

PolarisUSA Video, Inc. 13
Technological Arts 27

SOLAR ENERGY

LearnOnLine, Inc. 37

TEST EQUIPMENT

Circuit Specialists, Inc. 82-83
DesignNotes.com, Inc. 27
Dimension Engineering 37
Electronic Design Specialists 37
HAPRO Electronics 17
HobbyLab 27
Jaycar Electronics 36
LeCroy 5
NKC Electronics 27
Trace Systems, Inc. 55

TOOLS

NetBurner 7

WEB SERVICES

I/O Bridge 44

WIRE, CABLE AND CONNECTORS

DesignNotes.com, Inc. 27
Jameco 57
SparkFun Electronics 4
Abacom Technologies 38
ActiveWire, Inc. 27
All Electronics Corp. 3
AP Circuits 45
BaneBots 55
Cana Kit Corp. 71
Circuit Specialists, Inc. 82-83
Command Productions 26
Cunard Associates 27
DesignNotes.com, Inc. 27
Dimension Engineering 37
Electronic Design Specialists 37
ExpressPCB 56
Front Panel Express LLC 13
Fun Gizmos 27
Futurlec 44
General Circuits / PCB Cart 13
HAPRO Electronics 17
HobbyLab 27
I/O Bridge 44
Integrated Ideas & Tech. 44
Jameco 57
Jaycar Electronics 36
Lakeview Research 27
LearnOnLine, Inc. 37
LeCroy 5
Lemos International Co., Inc. 26
Linx Technologies 45
Lynxmotion, Inc. 45
microEngineering Labs 65
Mouser Electronics 9
NetBurner 7
Net Media 2
NKC Electronics 27
Parallax, Inc. ..... Back Cover
PCB Pool 36
PolarisUSA Video, Inc. 13
Pololu Robotics & Electronics 39
PrintAProto 27
QKITS 27
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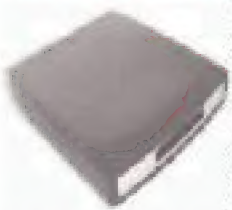

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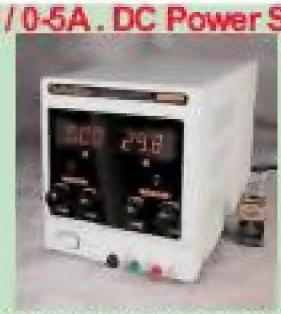
0-30V / 0-5A . DC Power Supply



The CSI530S is a regulated DC power supply which you can adjust the current and the voltage continuously. An LED display is used to show the current and voltage values. The output terminals are safe 4mm banana jacks. This power supply can be used in electronic circuits such as operational amplifiers, digital logic circuits and so on. Users include researchers, technicians, teachers and electronics enthusiasts. A 3½ digit LED is used to display the voltage and current values.

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Item # CSI530S **$79.00**

1st Place: Thumper by Harrison Pham - *Internet radio player with MP3 recording and playback capabilities. Has features not found in any commercial products & built for a fraction of the cost!*

2nd Place: DAQPac by Ryan David - *An automotive data logger for motorsports enthusiasts, with all the features necessary for a driver to improve both driving skill and vehicle performance.*

3rd Place: Sphinx by Michael Park - *Sphinx is a Propeller-based Spin compiler that compiles complex programs (including those containing Propeller ASM) such as the Parallax TV and graphics objects. Sphinx also performs some of the functions of an operating system. It provides a command-line shell, a text editor, disk utilities, and a memory-resident (cog-resident) I/O system.*

How will you use the Propeller chip?

With eight 32-bit processors (cogs) in one chip and deterministic control over the entire system, the multicore Propeller chip is inspiring. Witness this fascinating array of Propeller-based projects from the winners of our 2009/10 Propeller Design Contest.

Honorable Mention: Prop-Floppy by Sal Mustafa - *A floppy controller with a terminal interface and the ability to store images on memory sticks.*

HM: Prop RTOS by Peter Van der Zee - *A kernel for easily implementing multiple independent threads in any assembler cog, enabling the easy scheduling of the timing of triggers for all threads.*

HM: Propeller Powered Rock Band Robot by Adam Stienecker - *A system that can automatically play Rock Band on the xBox 360 using video analysis with a Propeller chip acting as the control platform.*

See all the winning projects at www.parallax.com/go/propellercontest. Order online or call Sales toll-free: 888-512-1024 (M-F, 7am-5pm, PDT).

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